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Potential of technology supported competence development for Maritime Education and Training

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Dedication

In loving memory of my maternal grandfather Shri Sharada Prasad Shukla

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Amit Sharma

Abstract

The ongoing technological advances are offering new avenues of exploration for maritime education and training domain. The increase in automation and digitalization is also correspondingly changing the operational profiles for the seafarers working onboard merchant ships and their competence requirements for various functions. The approach to prepare the future workforce of seafarers will require revisitation of the existing regulations regarding competence accreditation for the seafarers and identify the barriers and opportunities digital technologies present for the maritime industry stakeholders. The novel learning solutions facilitated by the information and communication technologies (ICTs) can allow the learning to be distributed and ubiquitous. However, the skills of both maritime students and instructors will determine how efficient is the adaptation and integration of technology. This thesis, through a series of individual research studies, investigates the potential of technology supported competence development for maritime education and training domain. The overall research questions which guided the thesis were: (1) What are the emerging competence requirements for the future maritime workforce and (2) What are the opportunities and barriers for technology integration in maritime educational settings? A total of four papers constituted the empirical investigation of the thesis. The papers examined the macro and micro contexts related to the competence development, technology integration as well as the professional development of the maritime instructors.

Paper-1 of the thesis examined the suitability of the present STCW regulations for Officers in Charge of a Navigational Watch. The scope of the study was narrowed down to the Table A-II/1 pertaining to the navigation officers in an operational role. An Exploratory Factor Analysis (EFA) of the Knowledge, Understanding and Proficiency (KUP) items, as rated on their relevancy by a sample of maritime professionals (n=109) was carried out. Furthermore, additional technical and non-technical competences for a hypothetical Degree-2 autonomous operation were listed. The results showed a new factor structure that synthesized into 11 competence themes which were rated as relevant for the future autonomous operations. These themes were identified as - (1) Position fixing and watchkeeping (2) Inspect and report defects to cargo spaces, hatch covers, and ballast tanks (3) Prevent, control and fight fires onboard (4) Contribute to safety of personnel and ships (5) Use of RADAR, ARPA, and ECDIS to maintain safety of navigation (6) Application of leadership and teamworking skills (7) Ensure compliance with pollution prevention (8) Damage control and distress communication (9) Application of meteorological information in navigation (10) Reporting and communication (11) Manoeuvring and maintaining seaworthiness of ship. Additionally, five main novel technical competency themes emerged - IT skills, safety and security management skills, knowledge of engine room operations, electronic equipment, and system integration. With respect to non-technical skills, the respondents rated the ability to maintain situational awareness and leadership skills as particularly relevant for the future. The novel non-technical skills that could be relevant for future autonomous operations were listed as - non-routine problem solving, self-regulation capacity, critical thinking, mental readiness, systemic thinking, the ability to develop trust in teams, the ability to adjust to cultural differences, and negotiation abilities. The findings from the study could aid in the competence modelling efforts for the future maritime workforce.

In paper-2 of the thesis, a survey study assessing the technology-proficiency of the maritime instructors (n=62), was carried out using a standard scale known as Technology Proficiency Self-Assessment for 21st Century (TPSA-C21). The results provided scores for the self-rated proficiency of the maritime instructors along six technical dimensions such as – Email, World-Wide Web (WWW), emerging tools, integrated applications, teaching with technology and teaching with emerging technology. Additionally, the data regarding the Level of Use (LoU) of various ICTs as per the Concern Based Adoption Model (CBAM) in maritime classrooms were collected. The findings indicated that the maritime instructors rated their proficiency relatively lower in using Web 2.0 tools (social media/wiki/blogs) compared to other general tools available to them. Furthermore, most maritime instructors rated their use of technology in the classroom at "routine" or "mechanical" levels against the higher levels on the scale expected from them. The findings hint at the reluctance to capitalize on Web 2.0 technology affordances by the maritime instructors and shed light on potential areas of improvement with respect to higher levels of technology integration in maritime classrooms.

With regard to ongoing educational innovations, Artificial Intelligence (AI) is generally discussed as having significant potential to transform learning experiences. The primary argument given towards the use of AI is related to the reduction of redundant tasks for the instructors and improving the overall efficiency. The paper-3 of the thesis attempted to provide proof of concept for adopting and using artificial intelligence (AI) in maritime classrooms. For this purpose, a conversational agent or chatbot for training the Collision Avoidance Rules (COLREGs) was developed. The chatbot titled "FLOKI" was introduced to the 2nd year Bachelor in nautical science students (n=18), and data regarding its usability was collected through the standardized System Usability Scale (SUS). The chatbot FLOKI received a score of 73.72 on the SUS questionnaire, which indicates an above-average performance in terms of perceived usability. No significant differences were observed in the responses by the students who had prior experience with navigation or chatbot interaction compared to those who lacked these experiences. However, an important result from the paper was also with respect to designing a distributed learning solution and demonstrating the use of a constructivist learning approach through the AI Chabot. The study intended to stimulate discussions around the pragmatic use of AI by the MET stakeholders.

Paper-4 of the thesis discussed the generic competence requirements for maritime students due to the impact of Industry 4.0 and digitalization. These skills are commonly referred to as the 21st-century skills. The final study in the thesis was carried out to measure one of the critical skills as per the 21st-century skills framework for education, namely the digital skills for maritime students. The standardized scale known as the Youth Digital Skills Indicator (yDSI) was utilized for this purpose, and the digital skills of a sample of maritime students (n=234) from B.Sc. nautical sciences and B.Sc. marine engineering disciplines, were measured along four dimensions – information navigation and processing skills, technical and operational skills, communication and interaction skills, and content creation and production skills. A Confirmatory Factor Analysis (CFA) was also carried out for evaluation of the factor structure of the scale. The results indicated that the students had relatively lower levels of information processing and content creation skills compared to other dimensions. In the increasingly digitalized learning and working environments,

the lower levels of digital skills in these dimensions could result in the limited capitalization of distributed learning modes by the students and presents itself as another avenue requiring targeted efforts by the MET stakeholders.

Through a mixed method design and use of standard scales predominantly from the learning sciences discipline, the thesis provided empirical evidence related to the novel competence requirements for seafarers, the level of technical skills of maritime trainees/instructors, and the theoretical structure of measurement models where applicable. In conclusion, the thesis advocates revisiting the technical competence requirements for seafarers and evaluating the suitability of existing competence themes under the STCW regulations. The growing importance of non-technical skills is also discussed. Furthermore, the role of distributed learning solutions that would be relevant to address the novel competence requirements is investigated. While discussing the technological affordances through digitalization, parallel consideration of relevant theoretical perspectives, such as the socio-constructivist view to complement existing practices, is suggested. The findings have implications for the maritime education and training stakeholders regarding contributing towards the ongoing discussions for the effective integration of technology in maritime classrooms and competence modelling for future seafarers. Based on the findings, areas of future research related to competence requirements for seafarers in different roles, alternative methodologies, and comparison of data from other geographical regions are suggested.

Keywords: Maritime education and training, STCW, digitalization, technology-integration

List of publications

Appended Articles

Article 1

Sharma, A., & Kim, T. e. (2021). Exploring technical and non-technical competencies of navigators for autonomous shipping. *Maritime Policy & Management*. DOI: 10.1080/03088839.2021.1914874

Article 2

Sharma, A., & Nazir, S. (2021). Assessing technology self-efficacy of maritime instructors: An explorative study. *Education Sciences*. 11 (1), 342-356. DOI: 10.3390/educsci11070342

Article 3

Sharma, A., Undheim, P.E. & Nazir, S. (2022). Design and implementation of AI Chatbot for COLREGs training. *WMU Journal of Maritime Affairs*. DOI: 10.1007/s13437-022-00284-0

Article 4

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Additional relevant publications

Sharma, A., Nazir, S., Wiig, A. C., Sellberg, C., Imset, M., & Mallam, S. (2018). Computer supported collaborative learning as an intervention for maritime education and training. In: *International Conference on Applied Human factors and Ergonomics* (pp. 3-12). Springer, Cham.

Sharma, A., Kim, T. E., & Nazir, S. (2021). Implications of Automation and Digitalization for Maritime Education and Training. In: *Sustainability in the Maritime Domain* (pp. 223-233). Springer, Cham.

Kim, T. E., **Sharma, A.**, Bustgaard, M., Gyldensten, W. C., Nymoen, O. K., Tusher, H. M., & Nazir, S. (2021). The continuum of simulator-based maritime training and education. *WMU Journal of Maritime Affairs*, *20*(2), 135-150.

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Abbreviations

AI – Artificial Intelligence

AIEd – Artificial Intelligence in Education

AIS – Automatic Identification System

AR – Augmented Reality

ARPA – Automatic Radar Plotting Aid

AVE – Average Variance Extracted

BDA – Big Data Analytics

CA – Cronbach's Alpha

CBT – Computer Based Training

CBAM – Concerns-Based Adoption Model

CFI – Comparative Fit Index

CR – Composite Reliability

CC – Cloud Computing

CFA – Confirmatory Factor Analysis

CoC – Certificate of Competency

COLREGs – International Regulations for Preventing Collisions at Sea

DPO – Data Protection Officer

ECDIS – Electronic Chart Display and Information System

EFA – Exploratory Factor Analysis

ES – Expert Systems

GPS – Global Positioning System

IBM SPSS – IBM Statistical Package for Social Sciences

ICS - International Chamber of Shipping

ICT – Information and Communications Technology

ILO - International Labour Organization

ITS – Intelligent Tutoring System

IMO – International Maritime Organization

IoT – Internet of Things

IT – Information Technology

LMS – Learning Management System

LoU – Level of Use

MET – Maritime Education and Training

MASS – Maritime Autonomous Surface Ships

NLP – Natural Language Processing

NSD - Norwegian Centre for Research Data

OICNW – Officer In Charge of a Navigational Watch

OICEW – Officer In Charge of an Engineering Watch

KUP – Knowledge, Understanding and Proficiency

RFPNW – Ratings Forming Part of a Navigational Watch

RFPEW – Ratings Forming Part of an Engineering Watch

RMR – Root Mean Square Residual

RMSEA – Root Mean Square Error of Approximation

SD – Standard Deviation

SDG – Sustainable Development Goal

STCW – Standards of Training, Certification and Watchkeeping

SUS – System Usability Scale

TPSA-C21 – Technology Proficiency Self-Assessment for 21st Century

TPACK – Technological Pedagogical Content Knowledge

TLI – Tucker Lewis Index

UK – United Kingdom

UN – United Nations

UNCTAD – United Nations Conference on Trade and Development

UNESCO – United Nations Educational Scientific and Cultural Organization

UNIDO – United Nations Industrial Development Organization

VR – Virtual Reality

WWW – World Wide Web

yDSI – Youth Digital Skills Indicator

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1 General Background and Introduction

"The wind and the waves are always on the side of the ablest navigator"

\- Edmund Gibbon

The maritime industry, since its inception, has consistently been recognized as an indispensable element in global trade and culture. The need for transporting various goods and essential services has increased manifold in today's interconnected world. The United Nations has termed shipping the "backbone" of global trade and economy (UN, 2016). The international seaborne trade accounted for about 10.6 billion tons of cargo being loaded and unloaded worldwide in 2020 (UNCTAD, 2021). As per the International Chamber of Shipping (ICS), more than 50,000 merchant vessels are trading internationally, transporting various types of cargoes. Over 1 million seafarers operate these ships from almost every nationality of the globe (ICS, 2020). These seafarers are working in the global fleet to transport essential cargo and services, day and night, to various parts of the world, thereby playing a vital part in ensuring the seamless functioning of the global economy. The safety of shipping largely depends on the competence, knowledge, and skillset of the seafarers working on ships.

Maritime Education and Training (MET) has been termed as one of the six pillars of the maritime industry by International Maritime Organization Secretary-General Koji Sekimizu during the 2015 World Maritime Day event (IMO, 2015). MET domain has been functioning over the years to ensure the standardization and uniformity in the competence and skills of the seafarers, passing through the various career channels available in the maritime domain (Manuel, 2017). However, MET is also expected to cater to the evolving nature of the maritime operations that require competent seafarers who can safely operate the ships and a modern workforce which possesses the skillset required to succeed in the evolving operational landscape of the 21st Century (Alop, 2019). The maritime industry has recognized the need for continuous professional development for the seafarers to ensure that competence development is not limited to achieving a Certificate of Competency (CoC) for the required rank but rather is reinforced throughout the career span (Ng & Yip, 2009).

The technological changes occurring in the recent years has been transforming the way organizations work and train their employees in general. The proliferation of digital technologies offer alternative models of vocational work, education and skills acquisition. With adaption of automation and digitalization, there is increasing recognition for the need for reskilling the workforce. In the face of such disruptive technology-driven changes however, the educational institutions, administrative systems and regulatory bodies can often struggle to make information-based policy decisions. In this regard, MET domain has similar challenges in terms of the lack of empirical evidence towards the potential impact of technology and the new competence and skillset required for the seafarers. The research problem for this thesis emerged out as the motivation to address this under-investigated area in maritime industry. The primary objective of the thesis was *to investigate the novel competence requirements relevant for the future maritime workforce, as well as the barriers and opportunities for integrating technology in the maritime educational settings*.

To meet the primary research objective, a series of individual research studies were carried out where different MET stakeholders such as industry professionals, instructors, seafarers and students were recruited to provide empirical data. There are a total of 4 research papers constituting the PhD thesis. The point of departure was the Standards of Training, Certification, and Watchkeeping (STCW) regulations governing the competence accreditation and eligibility standards for seafarers to serve in the maritime industry. The paper-1 of the thesis focused on investigating their suitability for advanced maritime operations as well as the need for additional technical and non-technical competencies for seafarers. Subsequently, the role of maritime instructors was explored for understanding the impact of technological adaption. The paper-2 of the thesis focused on the level of technology proficiency of maritime instructors and their level of technology integration for teaching activities. In terms of impact in education, Artificial Intelligence (AI) has been one of the most evident topics of discussion for learning sciences community. The paper-3 of the thesis focused on providing an example of potential use of AI based tool for the purpose of supporting teaching and learning in maritime classroom. The paper-4 of the thesis, with a focus on generic 21st century skills for the future, discussed the level of digital skills of maritime cadets. In order to provide overall context to the individual research studies and the PhD thesis, firstly, a general introduction and background is described of the STCW regulations, evolving maritime operations and current practices of MET. It is done with simultaneous discussion of the impact of technological changes and trends that are prevalent. Furthermore, the research objectives for the individual studies are elaborated upon. A conceptual framework is also provided to further describe the contribution of the findings for advancing understanding of the new competencies and the use of technology in MET. To discuss further the above-mentioned topics and the future competence requirements for maritime domain in the digital era, it is first necessary to describe the historical development and present state of the STCW regulations.

1.1 STCW framework for maritime industry

The International Convention on the Standards of Training, Certification, and Watchkeeping (STCW)'78, as amended, is the international convention that establishes the minimum competence standards that seafarers must meet before the flag state can provide them the CoC. (IMO, 2011). In this context, the flag state is any nation that has signed the STCW'78 convention, which ensures that the MET institute meets the convention's competency standards. The primary motivation behind the proposal and adoption of STCW'78 as amended, by the IMO was to promote uniform compliance in competence standards and promote safety at sea. The accidents such as *Torrey Canyon* (1967) and *Amoco Cadiz* (1978) have brought the attention of the global maritime fraternity to the importance of the human element in operational safety (Morrison, 1997). Prior to the STCW, the regulations proposed by the IMO primarily dealt with the design of ships and the provision of safety equipment onboard. The STCW regulations superseded the International Labour Organization (ILO) Officer Competency Certificate Convention (no.53). The STCW Convention was first adopted in 1978. The STCW needed to be ratified by 25% of the world's shipping tonnage to be fully implemented. This condition was finally met in 1984, and the regulations formally came into effect. The STCW regulations outline competence requirements for the onboard ranks such as – Master, Chief-mate, Chief engineer, Second engineer, Officer in charge of a navigational watch (OICNW), Officer in charge of an engineering watch (OICEW), Ratings forming part of a navigational watch (RFPNW), Rating forming part of an engineering watch (RFPEW), Able seafarer deckhands, Able seafarer engine rating, Radio officers, Electro-technical officers, and other general crew members. The signatory states need to ensure that their standards must meet or exceed the minimum competence standards specified in various STCW chapters. Such a system, while not without its difficulties due to subjective interpretation of legislation, is an attempt to ensure uniform compliance. The STCW convention has been revised on a regular basis (for example, in 1995 and 2010), to reflect current changes in the maritime sector.

After the STCW came into effect, it was observed by the shipping community that some parts of the regulations were still open to interpretation and lacked clear guidelines. The phrases such as "To the satisfaction of the administration" in the STCW created varying interpretations by various signatory states. Furthermore, several changes in the operational aspects of shipping required revising and specifying the regulations in greater detail. As a result, in 1995, amendments to the STCW Convention were adopted. These amendments came into effect in the year 1997. The amendments divided the STCW code into two parts. Part A was of the code was deemed mandatory, while Part B consists of recommendations. This move made the administration of the regulations easier and allowed for swifter future changes. In 2007, a comprehensive review of the STCW convention and code was initiated by the IMO, which culminated in the form of the 2010 Manila amendments. The 2010 Manila amendments were formulated in light of advances in the operational technologies used onboard as well as heightened security-related developments post year 2001. The 2010 Manila amendments to the STCW entered into force in 2012 under the tacit acceptance procedure (Parsons & Allen, 2018). As of 2018, the STCW convention was ratified by 164 shipping nations, representing 99% of the world's shipping tonnage. In the era of increased automation and digitalization of maritime operations, appropriate regulatory framework and research insights will be needed to prepare the future seafarers which can function effectively and safely with smart ships (Burke & Clott, 2016). As such, further revision of STCW can be expected in the coming years to take into account the digital evolution of maritime domain.

The above-mentioned framework of STCW regulations for standardized assessment of seafarer competence has received its fair share of criticism for its apparent shortcomings. For example, Sampson et al. (2011) in their study highlighted the challenges related to the meeting the competence criteria for the seafarers. They noted that the process of obtaining the CoC has varied standards in different signatory states, and it can therefore result in an unreliable measure for the employers of these seafarers. The shipping companies and fleet managers, as a result, try to compensate for this by their own in-house training requirements. They also highlighted that the differing interests of various stakeholders involved in this process can further compound the challenges. Ghosh et al. (2014) illustrated with examples the decontextualized nature of assessment of competence and as a result the failure by the seafarers to apply it in an operational scenario which could ultimately lead to serious incidents. Furthermore, they stated that the assessment process of the competences for the seafarers can miss their mark, by the failure to take into account all necessary facets of skills that would need to be addressed. If complete range of skills (both technical and non-technical) for a particular competence is not being assessed, it could potentially lead to a situation where the seafarer is not able to apply their knowledge in a holistic manner during the operations. Such existing challenges for the MET stakeholders can further exacerbate in the cases of novel skills requirements which naturally take place for any industry due to technological advancements. It is therefore imperative to gain deeper understanding regarding the competence requirements perceived to be critical for seafarers in the coming years.

1.2 Evolving maritime operations

It can be argued that the skillset necessary for the seafarers to effectively perform their duties have always been a function of the technologies at use on ships (Manuel & Balmer, 2020). Due to advancements in fundamental technology, the ships have also evolved over time. The shipping industry has progressed from the "Age of Sail" when ships used sails as propulsion means (Carter & Carter, 2010), to steam-powered ships, and finally to today's ships, which use a variety of propulsion modes (such as, electric/nuclear/diesel), as well as modern navigational technology to carry out various operations (Paul, 2020; Inal et al., 2022). The competence requirements for present day seafarer, therefore, is markedly different than the ones from previous era (Emad et al., 2022). For instance, Jurdzinski (2018) has described the transitioning of the maritime navigational model from mid-20th century to the present model of 21st century. He describes the modern navigational bridge in detail, which receives a large part of necessary information from reliable sources than what was available to the predecessor systems. This information is also integrated and presented in such a form to the bridge team to ensure efficiency. In the previous generation of navigators, the reliance was on paper charts for example, along with elementary level of support from the shore through radio signals. There was limited to no availability of satellite systems. In the case of modern navigators, understanding how to operate various bridge technology such as - Electronic Chart Display and Information Systems (ECDIS), Global Positioning System (GPS), and Automatic Identification System (AIS), Radar, and Automatic Radar Plotting Aid (ARPA) has become critical (Pazouki et al., 2018).

The maritime industry is going through a steady transition, since it operates in a constantly changing environment affected by digitalization. The digitalization phenomenon for the maritime industry is not new; however, the scale and the pace of the changes are noticeably higher in the recent years (Scanlan et al., 2022). It can be argued that there have been sub-optimal results in some cases when departing from traditional methods of operating a ship. For example, there have been groundings and collisions not despite of having navigational equipment such as ECDIS and RADAR but because of it. However, in such cases after a careful analysis, the root cause usually has been attributed to the incorrect use of such navigational equipment or their lack of integration in the navigational environment of ship (Turna & Ozturk, 2020). The aforementioned equipment have on the contrast greatly increased the information processing abilities of ship crew. The main premise of introducing any technological change has been efficiency and safety. The maritime business and operational scenarios currently are rapidly changing as a result of technological advancements, particularly new digital technologies and "Industry 4.0" often known as the fourth industrial revolution (Ichimura et al., 2022). Some examples of such technologies refer to – Artificial Intelligence (AI), Big Data Analytics (BDA), Virtual and Augmented Reality (VR/AR), Internet of Things (IoT) and Cloud Computing (CC) (Sanchez-Gonzales et al., 2019). Businesses are implementing digital technologies to increase productivity and remain competitive. In spite of the promise of Industry 4.0, some barriers to its implementation are also recognized. Lack of employee readiness or the lack of understanding regarding interplay between human and technology dimension of their organizations can often result in businesses not being able to capitalize on perceived benefits (Stentoft et al., 2019). To maintain effective, sustainable operations and improve short and long-term competitiveness, maritime stakeholders must rethink and adapt their current strategy in this regard (Babica et al., 2020). These developments also impact the MET community and their outlook towards preparing the future generation of seafarers. The incremental nature of changes in the maritime operational domain means that not only do the MET stakeholders need to cater for changing competence demands but also take into account the appropriate framework to best inculcate the requisite skillset. It can therefore be stated that technology has a twofold influence in the ongoing efforts to prepare the future workforce of the sea. Certain competence requirements can become obsolete with the digital advances in the maritime workspaces, whereas seafarers would be required to acquire some novel competence requirements (Pazaver et al., 2021). For example, with the transition from paper charts to ECDIS, the navigators onboard were required to simultaneously adapt and become proficient with the use of ECDIS and the conventions on corresponding vector charts. Similarly, the changes in the propulsion system and radio communication required revision in the competences of engineers and radio communication officers respectively. There are numerous such examples in the recent years. Furthermore, some of the major maritime nations are also expecting the deployment and the use of Maritime Autonomous Surface Ships (MASS) in the coming years (Goerlandt, 2020). In this regard, The International Maritime Organization (IMO) has undertaken a regulatory scoping exercise anticipating the possible introduction of autonomous ships and defined four degrees of autonomy for ship operations (IMO, 2018), as depicted in the Figure 1 below.

The arguments for introducing autonomous ships range from economic benefits associated with higher efficiency to safety concerns (Brandsæter & Knutsen, 2018). Porathe, Prison, and Man (2014) cite four primary arguments for adopting autonomous ships: improved work environment, cost savings, emissions reduction, and increased safety. In the opinion of the author, the potential introduction of autonomous shipping would be gradual, and the fully autonomous ships are not on the time horizon for the immediate future. However, the introduction of semi-autonomous ships has the potential to result in new modalities of ship transportation beyond those already available (Sharma & Kim, 2021). These changes are following the already existing trends of the recent decades in the shipping with respect to reduction of onboard crew and the functional allotment of an increasing number of operations to either shore or to autonomous agents (Burke & Clott, 2016). The seafarers operating in the Degree 2 and 3 of MASS operations will accordingly require different skillsets and educational approach than the existing traditional framework.

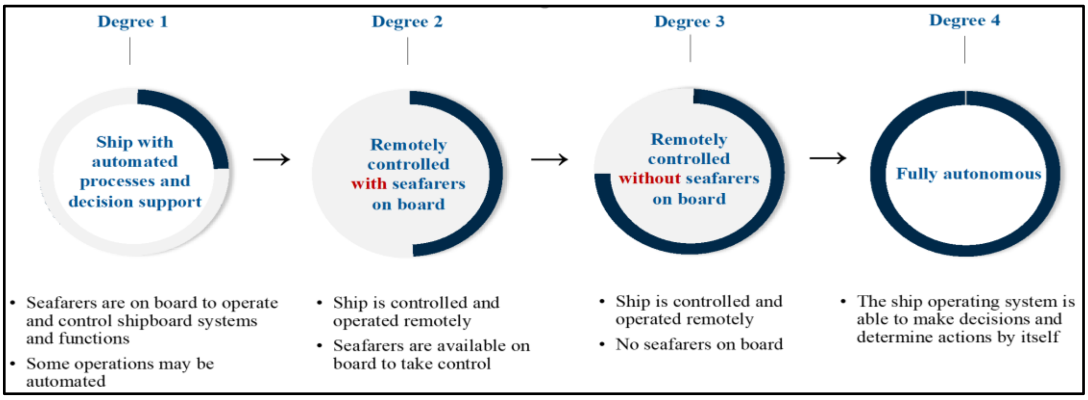

Figure 1. Degrees of autonomy as defined by IMO, adapted from Sharma and Kim (2021)

In the above-mentioned evolving scenarios for maritime operations, Maritime Education and Training (MET) institutes play a critical role in ensuring that the maritime industry has a competent workforce. Not only do MET institutes require suitable infrastructure to support several modalities of instructional content delivery, but maritime instructors must also maintain a current pedagogical profile and probe the use of digital technology. The need for professional development of the MET instructors have been argued in the recent past. However, most of the research articles in this regard have dealt the topic either at an abstract level, offering broad recommendations or at purely conceptual level. For example, Muirhead (2004) had written extensively regarding technological developments with advances in computing and processing powers of the multimedia tools and gave a broad framework for their integration in MET practices. He also advocated for the need for familiarization courses for the MET instructors in such instances. Similarly, Gamil (2008) advocated for the capacity development of the MET instructors as an integral part to raise the overall standards of the MET as a response to evolving maritime operations. His conclusion was based on a survey study of maritime stakeholders. More recently, Vujicic et al. (2022) examined several factors such as professional development, personal characteristics and classroom performance that influence the effectiveness of the MET instructors. In summary, it is recognized that the role of MET instructors cannot be ignored when discussing about the future roadmap and skill development of the prospective maritime workforce.

1.3 Maritime Education and Training

A properly trained workforce is the critical component in any complex socio-technical system. Emery and Trist (1960) first used the term “socio-technical systems” to describe work systems characterized by intricate interplay among human actors, technological components, and the surrounding environment. This definition although sufficient when initially coined, can now be termed generic, which opens up the possibility of different interpretations according to the domain in question (Baxter & Sommerville, 2011). For the purpose of present work, the term complex socio-technical systems is used to describe high-risk domains such as aviation, railways, roadways and maritime domain where priority is given to safe and reliable operations due to considerable risk of harm to human lives as well as the surrounding environment should an accident occur. In the above-mentioned transportation domains, the training of human element has considerable impact to their performance in day-to-day operations and is enforced through regulatory measures. This is also true in the case of maritime industry where the STCW convention is the primary instrument used by the International Maritime Organization (IMO) for setting the standards of education and training of maritime workforce. Every member state, signatory to the STCW convention strives to ensure uniform compliance to the minimum competence requirements. In the case of maritime domain, the term Maritime Education and Training (MET) is used to refer to the sub-domain of the maritime industry involved in the education and training of the seafarers and preparing them for a career at sea. The standards, practices and regulations surrounding MET are subject to considerable attention within the maritime industry, due to direct impact on the safety of ships (Demirel & Mehta, 2009). There are several approved MET institutes in each of the signatory states of the STCW convention that are executing the work of training and accreditation of the qualified workforce. Various parts of the STCW cover requirements for different ranks as well as laying down the common minimum standards. The STCW certification procedure for seafarers can be understood through the following Figure 2. A hypothetical example of training for navigation or engine officer can be taken to further illustrate the professional trajectory of a seafarer. The minimum requirements to be completed before an individual can begin a career at sea is called the STCW basic training and is covered under the Regulation VI/1. While STCW basic training courses are mandatory for every individual aiming to start a career at sea (both officers and ratings), Certificate of Competency examinations are professional check points for navigation or engineering officers to advance in their ranks (Othman & Naintin, 2016). These officers in the process, address all the requirements listed in STCW depending on the rank. A navigation or engine officer need to steadily acquire sea experience while passing COC exams, ultimately reaching a designation of Master or Chief-engineer. Additionally, specialized short courses are also taken by seafarers which target a generic area of competence usually common to more than one rank or designation onboard. The ship owner or the ship management company in charge of manning the vessel may require completion of additional in-house training for the seafarers employed by them which is over and above the basic and minimum STCW framework described above. The career progression can be visualized as shown in Figure 2.

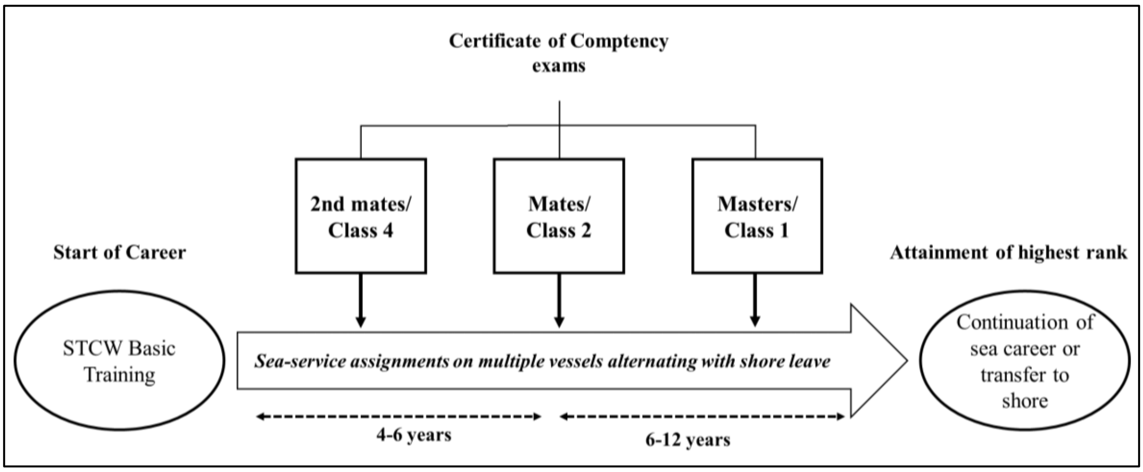

Figure 2. An example of career progression for a navigation or engineering officer

The above figure gives a contemporary illustration of the professional trajectory of a seafarer intending to be a navigation or engineering officer. As noted in previous section, the competence requirements for seafarers have changed parallelly to the technological changes happening on ships. In recent years, the pre-dominant model of training seafarers for prospective roles in the shipping was through an apprenticeship model. Such model required the seafarers to spend considerable amount of time at sea learning "on-the-job" through peers and immediate superiors in their respective department (Emad & Roth, 2008). However, an ever-increasing component of the contemporary seafarer's training now involves spending a significant amount of time mastering the basics and theoretical components of their job profile description. The sea-service remains relevant as well, but there is a cap on the time required to be onboard for advancing in the ranks as compared to recent years. Such hybrid mode of educating the seafarer for preparing for their job evolved from changing market dynamics as well as efficiency concerns. Additionally, there are varied options available for officers with regards to shore-based positions with the operational level experience (Pettit et al., 2005). Consequently, there is a tension between mastering the vocational and academic aspects of MET in the approach to prepare the future workforce (Manuel, 2017).

There are a variety of technological mediums available nowadays for the MET institutes to help them deliver the various learning components of a professional MET education. For theoretical components, traditionally, the classroom-based learning is employed with a selected number of lectures facilitated by an instructor. The instructors and the students can utilize a wide variety of ICT tools such as computers, smart phones, tablets, and learning management systems (LMS) to enable the transfer of knowledge and evaluate the learning outcomes of the classroom lectures. The practical demonstration of the skills is first carried out on a simulator station before being done onboard. The use of this approach provides a risk-free environment to attain the required skills for the students without the errors being translated into costs such as accidents or near misses onboard (Baldauf et al., 2016). The simulators utilized for skills training are of variety of types providing different levels of immersion and fidelity. MET institutes typically use desktop-based simulators for introductory exercises before utilizing full mission simulators to provide a more immersive experience of operational scenario. Furthermore, with evolution in technology, Virtual reality and Augmented reality based simulators are being developed that can allow even greater immersivity along with cloud based simulators which can allow for real time remote simulation based learning (Kim et al., 2021). Similarly, the educational delivery of the theoretical components is also changing as a result of the advances in ICT technology. In addition to the conventional mode of instructional delivery as described above, the more recent approaches such as Computer-Based Training (CBT) which allows a selected number of modules to be completed onboard on a laptop or desktop computer, during the seafarer's assignments on ships is introduced. Furthermore, the use of e-learning to connect to maritime trainees from different geographical areas, as well as the use of specific applications in personal devices enabling ubiquitous access to course content for the maritime trainees is possible for the theoretical component of maritime education and training (Collins & Hogg, 2004; Sokolov et al., 2020). For all these advances in ICTs, there are also bottle-necks and barriers existing for realizing applied benefits for education. Merely introduction technological solutions without considering the end goals could even turn out to be counter-productive in some instances with the demands of additional time and other resources. The effectiveness of these mediums in part depend on the role of organizational management, as well as skills and capabilities of both students and instructors. As noted by Miranda (2007), positive results from the use of technology only emerge when its use is considered holistically and when used as new form of processing educational information to better support the learning goals of the students.

The above-mentioned mediums provided a few examples of how learning content is delivered. In order to categorize them and understanding how learning is taking place, the learning framework of Harvard Professor - Richard Elmore can be utilized. According to Elmore (2016), there are primarily four modes of learning that can be categorized against two axes. These two axes represent individual or collective as a unit, forming opposite ends of one axis. Whereas the setting of learning can be hierarchical or distributed, forming opposite ends of the horizontal axis. Consequently, there are four modes of learning as per this framework, they are:

- Hierarchical Individual: Individual success and performance are the focus of learning in this quadrant. The structure of knowledge acquisition is chronological.

- Hierarchical Collective: Learning in this quadrant is similar to “hierarchical individual” learning in some ways, but it is centred on group engagement. The structure of learning acquisition is chronological.
- Distributed Individual: Learner in this quadrant initiates a learning process on his or her own, selects objects of study, defines sources and means, and establishes goals, with the assistance of internet and web 2.0 technologies.
- Distributed Collective: Learning is based on self-organized networks of people with similar interests. Members of such networks acquire and transmit information based on their level of understanding.

These four modes of learning and corresponding example from MET can be seen in Figure 3 below:

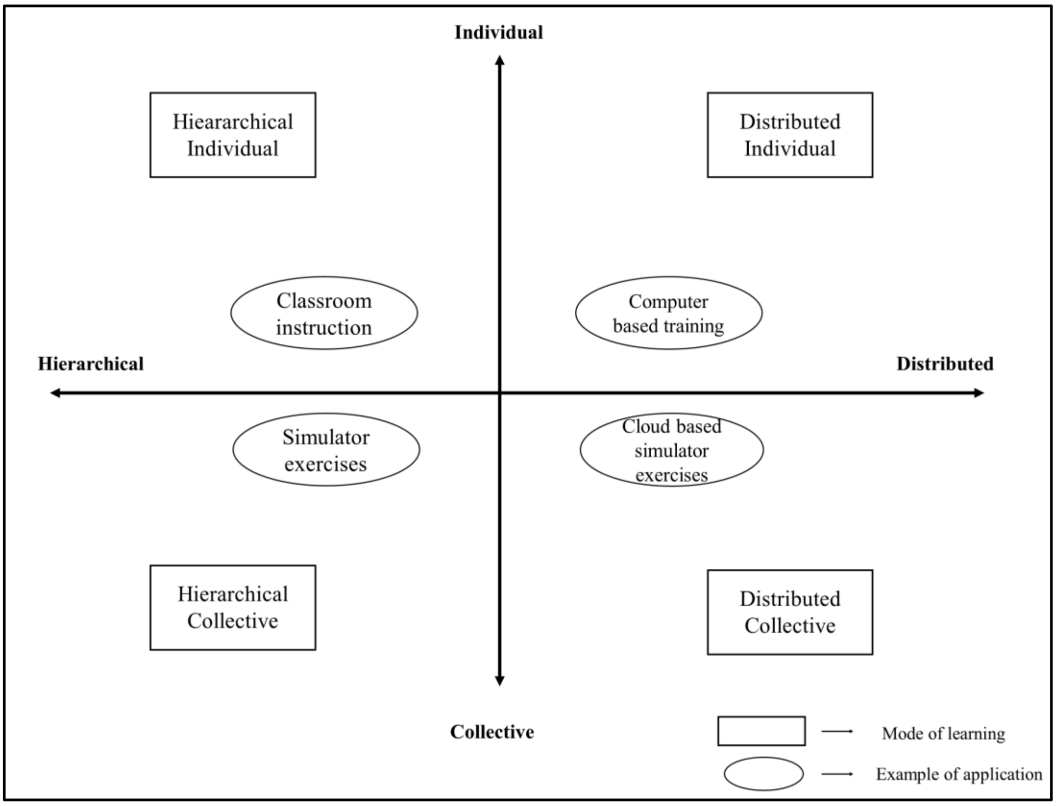

Figure 3. Modes of learning framework by Elmore (2016) and example of application within MET context

An example of hierarchical individual mode of learning in maritime context would be the conventional classroom instruction. The learning approach is structured and takes place in the physical setting of a classroom within MET institute. Similarly, the example of hierarchical collective mode of learning in a maritime context would be the simulator exercises taking place in the MET institute where the group of maritime trainees participate collectively as a group. The setting is structured as well, with clear learning objectives and performance indicators defined at both group and individual levels. As described above, with changes in the technology and capacities, the digital modes of learning, whether distributed individual or collective, are also being introduced for the MET stakeholders. An example of distributed individual mode of learning would be CBT or e-learning initiatives with personal devices as described earlier, whereas the use of cloud simulators or virtual worlds to form a community of learners for maritime students would fall to the distributed collective learning mode. There are several examples of commercial or governmental organizations providing e-learning and computer-based training solutions. The International Maritime Organization (IMO) itself offers a selection of e-learning courses on its LMS (IMO, 2022). Whereas technological companies such as Kongsberg Digital and Wartsila have initiated cloud-based simulator solutions during the Covid-19 pandemic (Kim et al., 2021). The increasing adaption of these digital distributed learning solutions does not negate the use of traditional hierarchical modes of learning, but they can be increasing thought as complementary to each other. With greater technological affordances available for the MET community, the options to use the relevant learning modes that offer shortest path to the learning objectives while also being economical will be considered. A common concern so far in the standardized mode of delivering education and training is also the issue of lack of personalized feedback (Mallam et al., 2019). This would be another area where the use of technology can be explored. In general, the distributed learning modes will be increasingly used in MET. In this regard, digital technologies such as Artificial Intelligence for example, can play a major role in the educational innovation.

As noted earlier, an indispensable element in the preparing the next generation of the seafarers is the role played by the MET instructors. The MET instructors have the key responsibility in designing and delivering the educational programs which are aligned with the industry standards. Therefore, their professional development is also a factor to be considered for ensuring that the students are equipped with the correct skills and knowledge (Vujicic et al., 2022). The relevant sections of the STCW regulations that detail the requirements related to the qualifications of the MET instructors are A-I/6 and A-I/8. Furthermore, non-mandatory suggestions and guidance are given in the sections B-I/6 and B-I/8 regarding compliance. Additionally, for ensuring compliance and to ensure adequate qualification standards for the instructors, IMO has also developed model courses, namely IMO model courses 1.30, 3.12, 6.09 and 6.10. The IMO model course 1.30 is towards the in-service, onboard competence assessment of seafarers and is therefore targeted for senior ship officers. Whereas the courses 3.12 and 6.09 addresses the classroom training and assessment methods and organization of instruction. The IMO model course 6.10 specifies the guidelines for instructors who will be involved with simulator-based training and assessment. These IMO model courses together along with other quality assurance mechanisms ensure that the MET instructors who are responsible for holding the examinations for the CoC of seafarers remain sufficiently prepared themselves. However, similar to the competence accreditation framework of seafarers, variation at national level exists in this regard. The phrasing of the regulation A-I/6 mentions that each party (signatory state) should ensure that the MET instructors are “appropriately qualified”. While accounting for natural differences in resources and organizations globally, it also leaves the phrasing open for different interpretations. Albeit it does not absolve the responsibility for taking into considerations the latest changes in new technologies that might require re-calibration of institutional efforts to prepare the MET instructors to better align with the ongoing demands. The consideration of such steps will require continuous discussions for capacity building of instructors and identifying the potential use of new educational technologies that could be leveraged for the benefit of achieving intended learning outcomes.

1.4 Conceptual framework of the thesis

The aforementioned trends in the maritime sector point to an anticipated shift in the industry's operational profile and, by extension, new competence requirements for seafarers. Further, with advances in digital technology, newer modes of learning and the content delivery that also take into account the distributed mode of education are forthcoming. Responding to contemporary technological changes would require maritime educational institutions to equip seafarers with "future ready" skill sets. It can be observed that such developments are impacting multiple facets of MET. The areas where transformation in approach for MET is required could be multiple and overlapping. Therefore, it is essential to understand the interplay of various factors that could influence the route taken by the MET stakeholders as well as the barriers and opportunities existing as a result. The present thesis is an attempt to contribute in the current and ever-increasing body of knowledge aimed at tackling the above mentioned challenges for the maritime domain.

To systematically consider these changes and advance our understanding regarding the new competence requirements, as well as the potential use of technology, it is necessary to have a holistic perspective of various factors that are interplaying in an educational context. Therefore, a conceptual framework for the PhD thesis was formulated. Basically, the factors discussed above which are influencing MET can be divided into three areas – (1) Macro-context (2) Professional development of MET instructors, and (3) Micro-context, as shown in Figure 4 below.

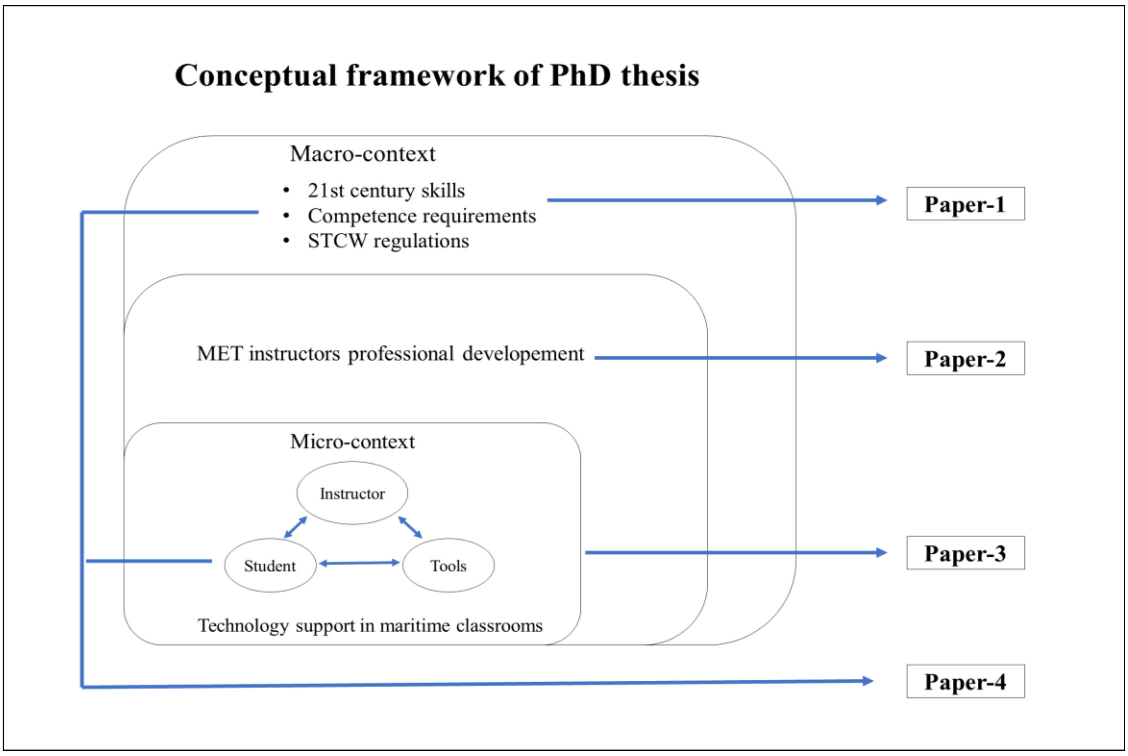

Figure 4. Conceptual framework of the PhD thesis

Macro-context related to the use of technology in MET pertains to more abstract view of the developments shaping the maritime industry at large and is dependent on various factors. For the purpose of current work, it was identified as the need for new competencies as a result of changing operations, the standards as per STCW regulations and the generic 21st century skills requirement for contemporary learners. Further understanding of the macro-context could aid in making informed decisions and pin-point areas where specific adaptations can be made. Paper-1 and paper-4 of the thesis focused on the macro-context. By investigating the suitability of existing STCW regulations and additional competence requirements for future maritime operations, paper-1 aimed to bridge the knowledge gap with respect to current standards which are used to prepare the seafarers and the demands with respect to the prospective new skillset. Another critical area which determines the use of technology in MET is the professional development of the MET instructors. MET instructors are directly responsible in imparting the education for the maritime trainees and their own level of advancement in technology can significantly influence its use in instruction and subsequently the capabilities of the students. Paper-2 of the thesis therefore focused on technology proficiency of maritime instructors and their level of technology integration. Micro-context refers to the specific instances of classroom activities where learning is taking place. For the purpose of the current work, they can be described as the instances where interaction between instructor and student takes place mediated by technology tools. By understanding how technology can be used to support these interactions to the benefit of both instructors and students would be valuable for evaluating its viability. Paper-3 of the thesis with the development and use of AI tool reflect on the micro-context. The paper-4 of the thesis shed light on the topic of digital skills of the maritime trainees, which is identified as one of the important skills required for industry 4.0 environments. The level of digital skills has also impact on the ability of learner to optimally use technology for their own learning. Paper-4, while mostly concentrating on the micro-context, simultaneously also touches upon the macro-context area of MET as described above. The conceptual framework was used to develop the research aims and objectives of the thesis as outlined in the next section.

1.5 Research aims and objectives

The research project set out to achieve the aim of the conceptual framework by a series of studies which focused on macro and micro contexts of the MET and the issue of the professional development of the maritime instructors. Based on the conceptual framework described above, specific research questions were developed for the thesis. The overall research questions which guided the thesis were:

(1) *What are the emerging competence requirements for the future maritime workforce and*

(2) *What are the opportunities and barriers for technology integration in maritime educational settings?*

The following research objectives were established for this purpose:

- To investigate the suitability of the present STCW competence requirements and explore novel competence requirements that will be required for future seafarers.

- To evaluate the digital skills of maritime students in the context of generic 21st century skills and identify potential areas of improvement.
- To identify the state of art and the barriers for technology integration in the maritime classrooms.
- To design, test and validate a learning intervention in the maritime classroom and present a proof-of-concept for the use of novel digital tools.

The outline and structure of the thesis is presented in the next section.

1.6 Thesis structure

The thesis consist of six chapters in addition to the appendices with supplementary information. The four papers are also appended towards the end. The thesis is organized as follows – first a general background and context of the research work is presented in Chapter 1. This section lays out the contemporary discussions regarding the primary topic of research and the conceptual framework which laid the foundation of the subsequent work. In Chapter 2, a brief literature review of the some of the key theoretical concepts associated with the research studies is presented. Important terminologies are clarified and elaborated. Chapter 3, presents the methodology used in the studies and the overall research paradigm. The reliability, validity of the findings as well as the ethical issues related to the above mentioned studies are also described. Chapter 4 highlights the key findings from the research studies. The Chapter 5 provides the general discussions of the findings as well as specific methodological and theoretical discussions. The implications and future research directions are also provided. Chapter 6 provides the concluding remarks. The research contributions as well as stakeholder recommendations are outlined in this chapter. Finally, the thesis ends with supplementary information in the appendices along with the four appended research articles.

2 Theoretical insights

This chapter elaborates on the theoretical insights which were utilized in the research papers and the PhD thesis. The essential theoretical concepts and state-of-the-art are described, which are related to the research objectives of the papers. A summary and theoretical discussion is offered towards the end of the chapter which focuses more on the application of concepts for MET purposes.

2.1 Learning theories in education

Since education and training is an overarching theme in the thesis, it is first necessary to review and discuss the established learning theories in education. Learning theories seek to explain how knowledge gets observably engrained in an individual's memory. There are several theories existing in the research literature which are used to describe the learning process. As described by Kay and Kibble (2016), broadly they can be categorized as (1) Behaviourism (2) Cognitivism (3) Constructivism (4) Social cognitivism and (5) Social constructivism. These learning theories are further elaborated upon as follows:

2.1.1 Behaviourism

Behaviourism, sometimes referred to as behavioural psychology is a learning theory which states that all behaviours by humans (or animals) are learned through interaction with the environment by a process known as "conditioning". In simple words, a behaviour is simply a response to stimulus from the environment. The basic tenets of behaviourism started to emerge as early as the late 19th century through a series of experiments carried out by Twitmyer and Pavlov (Clark, 2004). Twitmyer popularized the term "knee jerk reactions" as he was conducting experiment with the subjects where they were tapped on knee a moment later a bell was ringed. Subsequently, the sound of bell ringing alone was producing the effect from the respondents, as if they have been struck by the hammer in the knee. Similarly, Pavlov (1897) and Thorndike (1905) produced identical results through various experiments primarily on animals. The term which was used to describe the effect of the stimulus was known as Pavlovian or Classical conditioning. It was Watson (1913) who introduced the term methodological behaviourism and aimed to formally connect the relation between stimulus-response to human psychology. According to Watson (1930), the human psychology can be best understood through observable behaviour rather than the internal processes within the mind. He argued that there is a simple and direct relationship between the stimulus, situation and the subsequent reaction taken by individuals. The concept of methodological behaviourism was extended by Skinner (1938) and he proposed the theory of operant conditioning in contrast to the classical conditioning. According to Skinner, the behaviour of an individual depends on the stimulus that occurs after the behaviour, which he termed as reinforcement. The reinforcement can be positive (added after the behaviour) or negative (removed after the behaviour) which determines how the behaviour will take shape subsequently. His position is often referred to as "Radical Behaviourism" as he argued that all of the psychological processes can be traced back to the associated stimuli. Even though behaviourism as a learning theory is widely discussed and applied since its conception, several limitations of the theory were also identified. The most prominent limitation of behaviourism was deemed to be its insistence to only take into account the observable behaviours of an individual and not the internal mental processes. This take was criticized as it removes the role of individual agency of the learners. Additionally, behaviourism as a learning theory could also be termed as overly simplistic and does not take into account other factors that shape a learner's experience. It is also argued that it fails to take into account individual differences that might be present in a group of learners (Brau et al., 2018). However, despite its limitations, behaviourism still remains an important applied learning theory in education. Some of the modern concepts which are used in today's classrooms such as feedback, assigning of grades and gamification of curriculum can trace their origins from behaviourist learning perspective.

2.1.2 Cognitivism

Cognitivism in the context of learning theories is the study of the human mind and how it is able to obtain, process and store information. In the middle of 20th century, cognitivism began to emerge as the more plausible theory to describe the learning process (Clark, 2018). In cognitivism, learning is described as taking place in stages and the learner is thought to transition between various states of knowledge. In contrast with the behaviourist perspectives, in cognitivism the emphasis is given towards what the learners know and the process through which they came to acquire the knowledge (Jonassen, 1991). The early theory of cognitive development was advocated by Piaget (1936) where he described four sequential stages of cognitive development occurring in children – (1) Sensorimotor stage (2) Pre-operational stage (3) Concrete operational stage and (4) Formal operational stage. Furthermore, he described the concept of "schema" as the basic building block of the learner behaviour. In simple terms, it can be thought of as the basic unit of knowledge. According to Piaget (1957) as the mental development takes place for the learner, the number and complexity of schema increases. The existing schemata becomes the foundation over which new schemata are formed. According to cognitivism, active learning is preferred over passive learning, where a learner should be able to engage in a meaningful task and apply their own thinking to execute it. The modern application of cognitivism is therefore towards problem solving activities and self-directed form of learning. Despite being received favourably by a significant section of learning sciences community, some limitations of cognitivism learning theory also emerged over the years. As described above, cognitivism learning theory espouses the view of sequential stages of learning. However, in subsequent research, many investigators found the importance of social factors which shape the level of knowledge regarding particular concepts for learners (Dasen, 1994). Similarly, Piaget would propose that the thought precedes the speech in a child's development, as the learning occurs sequentially. This is in contrast with the position of Vygotsky (1978), where he states that the development of thought and speech occurs together for a child and is dependent on the social interaction between child and more knowledgeable other (parent or guardian). In other words, sometimes contrary evidence was found regarding one of the central tenets of cognitivist perspective i.e., a sequential order of learning taking place in well-defined stages. Nonetheless, cognitivism remains a relevant lens for consideration, when designing curriculum and instructional strategies in the classroom. Some applications in modern classroom of cognitivism learning theory is - using surveys to map the existing state of knowledge regarding a particular concept for the learners and then tailoring the lessons accordingly. Furthermore, introducing the learning content sequentially and in sufficient quantity, so as to facilitate the assimilation and integration of the knowledge by the learners.

2.1.3 Constructivism

Constructivism is a term used to describe both epistemology as well as learning theory. In the context of learning theory, constructivism refers to how learners construct the understanding of their own environment through active engagement and building up on their past experiences. In other words, it is about the learners creating their own meaning through experiences (Bednar et al., 1991). Historically, the foundation of constructivist perspective of learning is complex and comprises of several similar models given by various theorists. The prominent voices within the constructivist perspectives with some overlap in their positions are - Dewey (1929), Vygotsky (1978), Bruner (1961) and Piaget (1957) for example. The position of Bruner and Piaget is often described as cognitive constructivism, whereas Vygotsky's theory is termed as social constructivism (described later). Dewey although working independently with Vygotsky had reached similar conclusions in his research regarding the social dimensions of learning, however his emphasis was on connecting education with real life experiences and often is described as pragmatist. The central assumptions within the constructivist perspective of learning are as follows – (1) Knowledge is actively constructed by the learners (2) Learning is a social and contextual process which involves meaning making (3) The instructor (or more knowledgeable peer) assists the learner to achieve desired level of knowledge and (4) Learner participates in well described context with established learning goals (Bereiter & Scardamalia, 1992; Lebow, 1995; Wilson et al., 1995). The practical application of constructivism learning theory in present day education are – group work and problem-based learning assignments. Furthermore, activities or tasks that promote the autonomy of student, while being minimally supervised by the instructor or peers are also an example. Even though constructivist perspective of learning has been found to be useful specially in the domain of vocational education and in pursuit of preparing student for real life scenarios, some limitations are also present when using this approach. Constructivism is often criticized for lack of structure in the environments designed for activities related to it. Additionally, it is often found to be difficult to evaluate the student progress and grade them objectively in such situations.

2.1.4 Social cognitivism

Social cognitivism learning theory is based on the belief that the learning occurs through dynamic interaction between an individual and the environment where observable behaviours are imitated. Social cognitivism has its roots in the social learning theory proposed by Bandura (1962) where he offered a criticism of the behaviourist perspective on learning and its inability to be applicable in real-life settings. Later, he revised the theory and termed it as "Social Cognitive Theory" (Bandura, 1977, 1986). According to Bandura (1977) there is reciprocal and dynamic interaction between triad of - (1) Personal factors influencing an individual (2) External environment and (3) Behaviour of the individual. Bandura did agree with the classic and operant conditioning explanations of the learning process. However, he posited that the learners involved in the learning activities have the capacity for self-organization and self-regulation. Furthermore, he emphasized the concept of observational learning where the learners imitate ideal "models" in their social context. As per the theory, for observational learning to occur, it was necessary that cognitive processing is taking place, as there is some thought prior to the imitation of models. Due to this position, social cognitive theory was able to act as a bridge between the behaviourism and cognitivism perspectives of learning. Some of the key constructs associated with social cognitivism learning theory are - goals, outcome expectations, self-efficacy and socio-structural variables (Bandura, 1986). These constructs are thought to be influencing the end behaviour of the individuals. Goals refer to the intention to perform a certain action. Outcome expectations are beliefs whether the action will have positive or negative consequences. The socio-structural variables refer to the environmental factors that influence the goal and as a consequence facilitates or inhibits a behaviour. Whereas self-efficacy is the confidence in one's ability to perform the said behaviour. Some identified limitations of social cognitivism learning theory are - its broad nature which encompasses several factors, but their interaction is not adequately specified and therefore it is observed to be difficult to operationalize. Some contemporary application of social cognitivism in the classrooms can be - targeted training for improving self-efficacy of learners for particular aspects of the tasks and self-paced online lectures for learners which enables them to exercise autonomy and self-regulation.

2.1.5 Social constructivism

Social constructivism learning theory also sometimes referred as the socio-cultural learning theory is a theory originally proposed by Vygotsky (1978). As briefly mentioned earlier, it builds on the constructivist perspective of learning, but it emphasizes on the social and cultural factors that influences the level of knowledge and its acquisition process for the learners. According to this theory, the knowledge is not passively acquired by the learners, but it is actively constructed through social interaction with peers and instructors. In other words, the knowledge does not reside "in the mind" as suggested by the cognitive perspective but rather resides in a particular social and cultural context. It is often termed as a "learner-centred" approach. According to Vygotsky, learning process occurs in two stages, where first it takes place at a social level and thereafter the knowledge is internalized by the learners building upon their past experiences and beliefs. Social constructivist perspective of learning gives importance to the process of collaboration and interaction between a learner and their environment. A central concept related to social constructivism is - the Zone of Proximal development (ZPD) which describes the role of More Knowledgeable Other (MKO) for guiding or scaffolding the learner to achieve more knowledge (Refer Figure 5 below). MKO is conventionally described as either peer or instructor. However, in modern context, MKO could also be an artificial intelligence agent for example. To describe the concept of ZPD, often three concentric circles are illustrated where the innermost circle represents the current state of knowledge for the learner and the second intermediate circle representing what learner can do with the help of MKO (through scaffolding process). The third and final concentric circle encompassing these two circles represent the level of knowledge currently out of the reach for the learner. As per the social constructivist perspective, the difference between the first and second concentric circle is defined as the ZPD. In other words, to expand the first and innermost circle representing the current state of knowledge, the second circle should expand which can be achieved through increased interaction with the external environment guided by the MKO. Furthermore, the concept of community of learners is also described in the social constructivist perspective. Community of learners refer to a group of students with similar learning goals who collaborate and work together to construct knowledge and increase their understanding. Some apparent limitations of the social constructivism learning theory is its inability to be applicable in a wide variety of learning settings. It is often limited to a more narrow and confined learning setting where there is an explicit need for collaborative approach. Furthermore, this approach to learning would be resource intensive in planning and execution to adequately realize the desired learning goals. Some modern day application of social constructivism learning theory are - group tasks where the role of instructor is minimal. The students are allowed to collaborate, describe and present their findings in a plenary discussion. Additionally, reciprocal teaching is employed at times i.e., students are given the task to prepare a small portion of curriculum and play the role of instructor for a brief period. These activities are instrumental in making the knowledge gaps explicit and allows the classroom to converge on the desired level of knowledge together as a group.

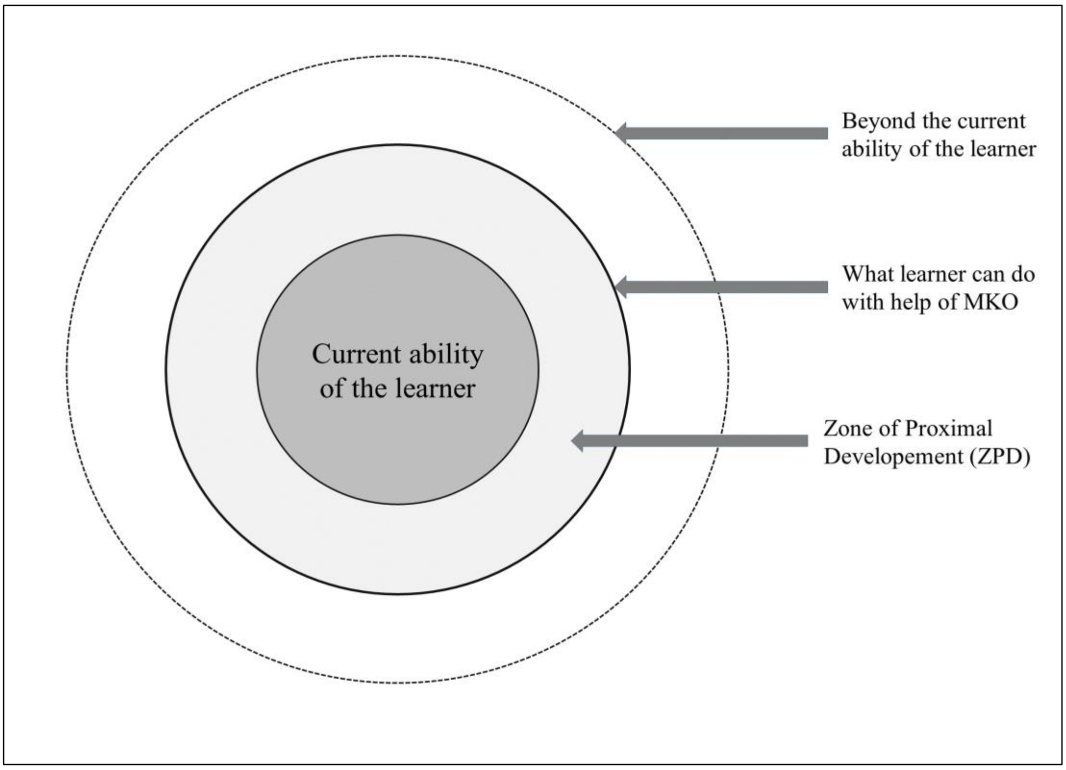

Figure 5. Zone of Proximal Development (ZPD) as defined by Vygotsky (1978)

2.2 The concept of competency

2.2.1 Competency

The term "competency" has a variety of definitions and interpretations in the literature. The Oxford English dictionary defines competency as "the ability to do something successfully or efficiently" (Stevenson, 2010, p.355). A more specific definition is provided by the United Nations Industrial Development Organization (UNIDO), which defines competency as "a set of skills encompassing knowledge and attributes which enables an individual to perform a task within a specific function/job effectively" (Vathanophas & Thai-ngam 2007, p.50). Historically, research on competency has discussed it in terms of an individual's performance and its surrounding environment (Hayes, 1979; Boyatzis, 1982). In this regard, one of the early attempts to define the concept of competence in terms of an operational definition was by White (1959, p.297) where he defined competence as "an organism's capacity to interact effectively with its environment". White (1959) argued that the psychoanalytic instinct theory or the drive reduction theory, which were the dominant psychological theories at the time were insufficient in adequately describing the construct of motivation.

To this end, he stated that an individual's desire to master the surrounding environment or being competent in their actions, leads to motivation which is reinforced through further interactions and feedback. He viewed this as an inherent trait in humans and thought of it as independent of biological drives or instincts. This view was influential in articulating the concept of competence further in the subsequent research literature. Although not explicitly discussing the act of acquiring knowledge, he indicated that competence is attained through prolonged acts of learning and exploration by an individual of their immediate environment. Afterwards, the concept and definitions of competence evolved, and it acquired a definite functional perspective. In the 1970s, McClelland (1973) argued that in the educational contexts, it is more appropriate to test the ability of students to manage with the real-life situations i.e., their competence in contrast to the traditional focus on intelligence diagnostics. Similarly, Hartig et al. (2008, p.6) have defined competence as "complex ability constructs that are closely related to performance in real-life situations".

Another and more recent perspective in discussing competency is to define it in terms of education or human resource development for individuals. In this regard, Mace (2005) described it as established personal qualities that demonstrate the ability to consistently perform at an acceptable or high skill level in a specific job function (Smythe et al., 2014, p.60). Shavelson (2010, p.44) gave a more overarching framework of the term competence and its measurement. He stated that competence is - "(1) is a physical or intellectual ability, skill or both; (2) is a performance capacity to do as well as to know; (3) is carried out under standardized conditions; (4) is judged by some level or standard of performance as "adequate," "sufficient," "proper," "suitable" or "qualified"; (5) can be improved; (6) draws upon an underlying complex ability; and (7) needs to be observed in real-life situations.". Thus, the conceptualization and adoption of competency as a concept can be seen as a step in the process of regulating and enhancing human performance in a particular situation through targeted education and training. (Hoffman, 1999, p.283).

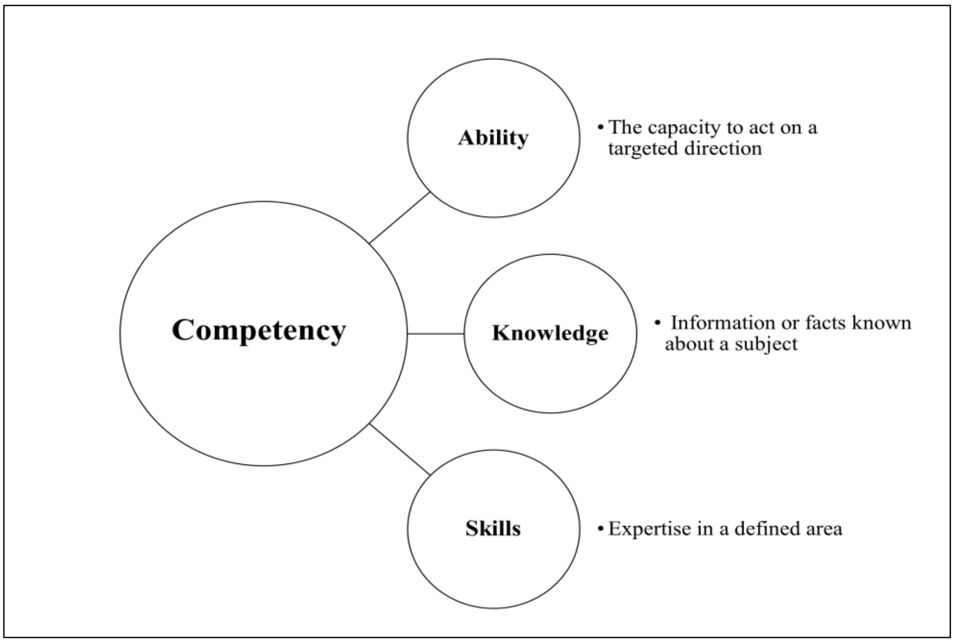

Figure 6. Various facets of competency such as ability, knowledge and skills

In light of the above definitions, it is worthwhile to emphasize the distinction between competency and skills. The phrase competency encompasses a larger range of employment needs than does the term skill. The definition of competence given by Rychen and Salagnik (2003, p.46) where they have defined it as “the ability to successful meet complex demands in a particular context through the mobilization of psychosocial prerequisites” clarifies the above assertion. Here the psychosocial prerequisites includes skills and attitudes. Thus, the phrases “skills,” “ability,” and “knowledge” are best used to refer to facets of competency in this context, as can be seen in Figure 6. There can be differences in scope when talking in relation to competence for a task or function. Therefore, it should be noted that competence for a function is always tied to a relevant real-life context. To give an example of the term in a maritime context - A navigator is considered competent if he or she is capable of successfully navigating the ship between two destinations. To accomplish this duty, they will require a specific set of talents (e.g., radar navigation, passage planning, etc.). Furthermore, there should be concrete description of the context in which their performance can be measured and compared.

2.2.2 STCW competence framework

Until few decades ago, Individuals entering the merchant marine were required to perform mandatory periods of minimum sea service in between advancing grades of license examinations conducted by the appropriate licensing authorities. Sea service provided the majority of the necessary practical experience and served as the foundation for additional instruction ashore. Long sea journeys, long turnaround periods, large crew compliment, and comprehensive apprenticeship programs, all helped individuals gain the necessary practical skills while at sea. However, there were also varying standards when determining the seafarer’s competency for the job (Alop, 2004). For the increasingly globalized maritime industry, it was imperative to have uniform competence standards, and this was the driving motive for the adoption of the STCW convention (Emad & Roth, 2008).

The STCW convention and its adoption process was described in earlier sections. There are various ranks and responsibility levels present in the hierarchy of manning arrangements for merchant shipping. The standards of competence and related general abilities for the seafarers in the STCW are grouped under seven functions, namely – (1) Navigation (2) Cargo handling and stowage (3) Controlling the operation of the ship and care for persons on board (4) Marine engineering (5) Electrical, electronic and control engineering (6) Maintenance and repair and (7) Radiocommunications (IMO, 2011). These functions are further having three levels of responsibilities – (1) Management level (2) Operational level and (3) Support level. The competence requirements for all the functions at each level of responsibility are grouped under various chapters of the STCW. Taken together, they constitute the STCW competence framework. There are several tables present in each chapter of the STCW Part-A, that enumerate the set of competencies that should be acquired before a Certificate of Competency (CoC) can be issued by an examining body for the candidate. Various methods of demonstrating the listed competencies may include practical demonstrations, oral exams, written exams and other forms of assessment. These competencies are divided into – *Knowledge, Understanding* and *Proficiency* (KUP) items. The focus of the competence related research for this thesis has been the “Navigation” function at an “Operational” level. For example, the Table A-II/1 which lists the competencies that an Officer in Charge of a Navigational Watch (OICNW) for foreign going ships over 500 Gross Tonnage should possess. It has 19 competence themes and 66 KUPs. Corresponding tables are also present for management level officers as well as ratings for various ship departments. The assessment of these competencies in the case of navigation officer for example, involves written assessments as well as practical evaluations. The written assessment of theoretical knowledge components typically include topics such as navigation, cargo handling, emergency preparedness, etc. and can be conducted in a classroom setting, or through computer-based testing. Whereas the practical evaluation is usually carried out onboard ship or in a simulator setting. It entails the demonstration related to the ability of the seafarer to carry out specific tasks associated to their job roles. In case of navigation officer, that would require tasks such as - navigating the ship under varying conditions from point A to point B, as safely as possible.

Once a seafarer is deemed competent to serve in a particular rank, they are issued the Certificate of Competence (CoC) as a formal recognition for their completed assessment. It signifies that they possess minimum level of competence necessary to perform functions related to their rank. Subsequently, they can be employed to any ship registered to a state signatory to the STCW convention. Furthermore, they can progress to more advanced ranks in their career and obtain corresponding CoCs or choose to go refresher training periodically to maintain the validity of the current CoC. The above description illustrates the current status of competence assessment framework for maritime industry.

2.3 Technology integration in education

2.3.1 Technology integration

Technology integration can be described as the process of incorporating technological tools in the classroom to improve the educational experience for students. Various technological resources such as - desktop computers, laptops, tablets, smartphones, multimedia devices and other innovative digital tools can be utilized by the instructors to achieve the curriculum objectives. Usually, the diverse form of digital tools used in education are described under the umbrella term of Information and Communication Technology (ICT) tools. The ICT tools can include both stand-alone and networked technologies used in the classroom by the instructors and the students (Livingstone, 2012). The use of technological resources is thought to be complimentary to the traditional approach of imparting knowledge by the instructors. If utilized effectively, the above-mentioned ICT tools can help instructors expand their reach and improve their efficiency in the classroom (Spector, 2014). In recent years, technological integration has received considerable interest in educational research. This phenomenon can be attributed in part to the rising availability of digital technologies in the production and distribution of instructional content (Guzman & Nussbaum, 2009). Some of the potential benefits of technology integration are listed as improved interaction, communication and collaboration and resource sharing amongst the students and instructors. The use of ICT tools and associated technologies can facilitate the process of active knowledge construction (An & Williams, 2010). However, critical reflections in the research literature regarding the use of technology for education have also emerged concurrently. Selwyn (2010) argues that wider analysis of influences regarding the technological developments is often missing in the learning sciences literature. He further states that too often in the studies involving the use of technology in educational settings, the focus is towards the micro-level of individual use with guidance from instructors. The study of macro elements such as global trends, organizational and cultural factors at institute and international levels could assist in socially grounded and pragmatic understanding of the educational technology. This could aid the research community in providing better answers regarding why and how the technology can be utilized for greater benefits of the learner community rather than focusing on narrow contexts and “means-end” approach. Similarly, Livingstone (2012) pointed out that the evidence that the introduction of ICT can improve learning gains might be ambivalent, as it has been historically difficult to evaluate the impact of any learning intervention and their outcomes. Furthermore, she highlights the fact that the optimal integration of technology for meeting learning objectives can be resource intensive, both in terms of infrastructure as well as preparedness of the instructors. In this regard, Saljo (2010) notes that the use of digital tools can challenge the established institutional traditions regarding learning as they alter the way knowledge is created, stored and shared. Instead of focusing on apparent effectiveness of these tools, he brings attention to the novel technological affordances and their potential impact. The digital technologies might offer new opportunities for collaboration and creativity for the learning communities, but they also creates doubt about reliability and authenticity of obtained knowledge. In sum, the use of technology does change the way education is delivered at the institution, however the effectiveness of their use is contested.

There are several technology integration frameworks and models developed as evident from the research literature, that can be used by the instructors and other stakeholders when deciding to utilize any technology for meeting learning objectives. One of the widely discussed model is the SAMR model of technology integration given by Puentedura (2006). SAMR stands for Substitution, Augmentation, Modification and Redefinition. It is a 4 level taxonomy utilized for selecting, using and evaluating any technology for supporting the classroom instruction. In substitution level, the focus is on directly replacing traditional activities or tools with digital counterparts. It can be as simple as having the lectures in a digital format such as presentation slides. The next level is Augmentation, and the technology is used to enhance the already existing system. An example in this regard could be use of multimedia to facilitate the delivery of learning content. In the modification level, as the name suggests, technology is used for fundamentally modifying the learning process. Use of dedicated Learning Management System (LMS) can be considered as an example of this level. Finally, at the Redefinition level, the technology is used to create learning experiences that are impossible at the prior three levels such as the use of Virtual worlds or other similar distributed mode of learning. Another important framework with regards to technology integration in education is known as TPACK framework proposed by Koehler and Mishra (2009). TPACK stands for Technological Pedagogical Content Knowledge. As the name suggests, the TPACK model states that the effective integration of any technology will rely on three inter-playing factors – (1) Pedagogical knowledge – the instructor’s own processes and practices related to teaching and learning (2) Technology knowledge – the understanding regarding the technology in use and (3) Content knowledge – the expertise related to subject being taught. It is built on Shulman’s (1987) model of pedagogical content knowledge (PCK) by adding technology as a separate dimension. According to Koehler and Mishra (2009), for technology use to be beneficial in any educational setting, it will require creation of continuous equilibrium of all three dimensions of TPACK. Another model utilized for understanding the role of instructors in technology integration is known as RAT. It stands for Replacement, Amplification and Transformation. It was conceptualized by Hughes et al. (2006). In replacement stage of the RAT model, the technology directly replaces the traditional method of teaching, whereas in the amplification stage, it is used to increase the productivity and efficiency of instruction. Finally, at the transformation stage, the technology completely redefines the learning activities in the classroom. In a way, the RAT model is closely related to the SAMR model with some parallels that can be drawn regarding how the use of technology is conceptualized. Similarly, TIM model which stands for Technology Integration Matrix, was developed by the Florida Centre of Instructional Technology in 2005. There are five distinct levels of technology integration as defined in TIM, they are – Entry, Adoption, Adaptation, Infusion and Transformation. Together with five characteristics of learning environment which are described as – Active learning, Collaborative learning, Constructive learning, Authentic learning and Goal directed learning; the TIM model has 25 matrix cells which describe the technology integration in any classroom. These are some examples of technology integration frameworks and models existing in the literature; however the list is not exhaustive. Each of the framework and model offers unique perspective for the purpose of technology integration and can be utilized by the instructors and other stakeholders depending on their needs and suitability. A much simpler instrument for determining the level of technology integration is Concern Based Adoption Model - Level of Use (CBAM_LoU). It is based on the concern-based adoption model for innovation diffusion (Hall et al., 1975) and can be used as a unidimensional scale having 8 distinct levels for measuring educational innovation (Knezeck & Christensen, 2016).

As use of technology is usually discussed at micro-levels, it will require some reflections from the educational stakeholders, especially the instructors to view the technology integration as a part of larger efforts to deliver on the learning outcomes and be a cohesive part of education program (Okojie et al., 2006). As was noticed in the above illustrated frameworks, for the technology integration to be truly successful, the use of technology should be coupled with the pedagogical strategy. The instructors form the critical link between the use of any technological resource for conducting learning in MET, to making its practicable use for the benefit of the students (Sellberg, 2017). Kim et al. (2013) in their study demonstrated that technology integration in the classrooms is co-related with the instructors' belief about the nature of learning and their beliefs about the effective ways for teaching. In the context of MET, the latest amendment to STCW in 2010 (Manila amendments) actively encourages the use of e-learning and distance learning measures for seafarer training and assessment (Wei, 2013). The utilization of technology and its adequate integration by the MET instructors will become an important factor for the success of such proposed measures. In this regard, Muirhead (2004) had stated that capacity development and MET instructor staff training will play a crucial role for the helping raising the future training standards for maritime industry. The progressive use of technology in MET will be complementary to the efforts of well-trained instructors to innovate the learning content delivery and assessment of learning outcomes.

2.3.2 Technology self-efficacy

When integrating technology for the purpose of delivering on the learning objectives, certain limiting factors or barriers are to be experienced by the instructors. Ertmer (1999) described them as first order and second order barriers for technology integration in classrooms. First order barriers refer to the factors which are external to an instructor's loci of control such as organizational factors or infrastructure. Whereas second order barriers are related to instructor's belief system. The usage of technology tools in the classroom by instructors is partly dependent on their self-efficacy toward them, as described in various studies (Brinkerhoff, 2006; Moore-Hayes, 2011). Self-efficacy relates to the confidence of an individual at their own abilities to perform certain actions. In other words, self-efficacy is an individual's belief that the task they are executing will result in the intended consequences. The concept of self-efficacy is based on the social cognitive theory proposed by Bandura (1977). According to Bandura (1993), self-efficacy could be a good predictor of behaviour. In the context of instruction in an educational setting, it is referred to be one of the aspects that determines teaching effectiveness (Hoy et al., 2009). The term technology self-efficacy by extension, can be described as “the belief in one’s ability to successfully perform a technologically sophisticated new task” (McDonald & Siegall, 1992). The concept of technology self-efficacy relates to an instructor’s belief in their ability to employ digital technology in the classroom. (Gomez et al., 2022). Technology self-efficacy has become important in the training of educators capable of successfully utilizing educational technology to increase learning (Holden & Rada, 2011; Spencer, 2016). It is a predictor of and positively co-related with actual technology integration in the classroom (Anderson et al., 2011). Low self-efficacy of instructors with respect to use of technology can act as a barrier for technology integration in the classrooms (Harrel & Bynum, 2018).

Measuring and improving instructor’s self-efficacy in the use of technology tools might thus aid in their capacity development. In this context, Christensen and Knezeck (2017) suggest that in current educational institutions, the ability to integrate 21st-century technology for learning and skill in its usage is critical (Sharma & Nazir, 2021). They developed the Technology Proficiency Self-Assessment for the Twenty-First Century (TPSA-C21) as a validated instrument for assessing instructor’s self-reported self-efficacy scores in light of the most common technological instruments used in today’s classrooms. Christensen and Knezeck (2014, p.312) explore the theoretical foundations of the scale, stating that it is based on the notion of “Self-efficacy”, which they describe as “confidence in one’s competence”. The scale is based on Ropp’s older version of the instrument, called Technology Proficiency Self-Assessment (TPSA) (Ropp, 1999). The instructor’s perceived technology self-efficacy and digital competency became a focal point for educational stakeholders in various domains in the wake of the recent covid-19 pandemic (Ma et al., 2021; Pressley & Ha, 2021).

2.4 AI in education

2.4.1 AI in education

Digitalization in education refers to the use of personal computers, mobile platforms, internet, software solutions, and other types of digital technology to educate students of all ages (Frolova et al., 2020). The world-at-large is changing as a result of the capabilities of advanced technologies and shifting societal expectations. This is also resulting in disruption of the workplace and consequently the educational requirements for the individuals at those workspaces. The widespread use of digital technology in education has an impact on both teaching and learning practices, as well as providing access to data, mostly from growing online learning environments, that may be utilized to improve learning conditions for students and teacher support (Siemens, 2013). The use of technology in the classrooms is resulting in significant generation of associated data and digital footprints that can be analysed by the educational stakeholders to further improve the learning activities and contribute to active policy making and strategic decisions. In this regard, the use of Artificial Intelligence (AI) will play an important role in making sense of the emerging educational data. The use of Artificial Intelligence (AI) has the potential to solve some of the contemporary problems in education, provide new ways of learning and teaching, and contribute towards the achievement of SDG 4 goal (UNESCO, 2019). The adoption of AI in education has coincided with advancements in the educational technology itself, providing several functional advantages (Zawacki-Richter et al., 2019). According to UNESCO (2021), the relationship between AI and education can be imagined in areas like – (1) Learning with AI (Use of AI enabled tools in classrooms) (2) Learning about AI (opportunities and limitations) and (3) preparing for AI (enabling the global citizens to understand the wider impact of AI). Artificial Intelligence in Education (AIEd) has gradually advanced from personal computers to online/web-based learning systems. The present use of embedded systems and other technologies made possible by increased processing power has had an impact on how education is delivered (Chen et al., 2020). Several studies have highlighted the potential of AI to increase classroom engagement, decrease redundant tasks, tailor educational content, and uncover learning gaps (Owoc et al., 2021; Schiff, 2021).

According to Timms (2016), AIEd will go beyond simply offering education through personal devices in the future to provide new solutions for learning and teaching activities. One of the many potential AIEd alternatives is the development and employment of “educational cobots” designed to aid human educators. These cobots help learners stay engaged by answering simple inquiries. Through a social network analysis of the associated literature, Goksel and Bozkurt (2019) established that concepts such as Expert Systems (ES) and Intelligent Tutoring Systems (ITS) have stayed at the forefront of AI-related educational research. This concept is being reinterpreted as intelligent agents or systems that may steer humans towards learning objectives, while also supporting them in navigating the associated process. This phenomenon can be attributed to specific improvements in AI, namely in the domain of Natural Language Processing (NLP). These developments are also consistent with the growing examples of human-automation agent collaboration in a variety of job tasks. It is observed that the Intelligent agents are increasingly being delegated monotonous and repetitive tasks. The usage of chatbots in education is a result of the AIEd advancements mentioned above. Despite considerable promises for the use of AI in education, some specific challenges have also been stated in the emerging studies. Most evident challenges related to the ethical handling of emergent data and reduction of bias in the algorithms being utilized (Borenstein & Howard, 2021). Additionally, challenges such as the need for ensuring equitable learning outcomes as well as providing equal access to learners among other issues are also frequently mentioned (Woolf et al., 2013).

2.4.2 Conversational agents or chatbots

A conversational agent or chatbot is a computer software that simulates dialogue with human agents (Adamopolou & Moussiades, 2020). As technology advances, more organizations are shifting from traditional to digital platforms to interact with partners or clients. These organizations are striving to provide convenience through technology by adopting AI techniques on their digital platforms. Chatbots are one of the AI technologies that is becoming more popular and widely used. Recently, the AI tool designed by OpenAI© – ChatGPT has become one of the most discussed topics in technology trends. ChatGPT has rapidly progressed to acquire 1 million users within a week of its launch, beating many past technology products in the process (Rudolph et al., 2023). It is a relevant example demonstrating the potential of AI Chatbots. Chatbot technology includes virtual conversational assistants such as Amazon’s Alexa and Google Assistant, as well as bots in messaging apps such as Meta’s Facebook Messenger. In similar measures, educational institutions are exploring deployment of conversational agents or chatbots for addressing their goals (Neto & Fernandez, 2019; Clarizia et al., 2018). Customer service and education are two key areas of application for chatbot research and development towards the coming years (Følstad et al., 2020). Chatbots can act as virtual advisors, adapting to the students' abilities in the process and their rate of learning. The use of NLP to develop conversational agents for educational use is one of the varied applications of AI for education. Chatbot development and implementation has been occurring parallel with AI research. The first known chatbot, "ELIZA", was created in the 1960s and was programmed to serve as a psychotherapist (Weizenbaum, 1966). Since then, chatbot technology has advanced steadily and strengthened NLP skills with numerous applications in various business/operational contexts. An educational chatbot can replicate conversation and idea exchange for practice with low-stakes skills. Similarly, they can be good tools for memorization related tasks. Some of the evident benefits regarding the use of chatbot for learning activities can be listed as personalized learning, ubiquitous access, faster feedback and greater engagement. There has recently been a rise in research papers aimed at evaluating the applicability of chatbots in educational contexts. Okonkwo and Ade-Ibijola (2021) conducted a systematic review of the literature on chatbot uses in education. They mentioned some of the key benefits of employing chatbots in education as integration of instructional information, greater motivation and engagement, ubiquitous access, and simultaneous use by numerous learners. They also provide insight on some of the challenges related with chatbot use, such as usability and evaluation issues, ethical concerns, programming considerations, and so on. Likewise, Rapp et al. (2021), utilizing a human-computer interaction lens and a literature analysis, highlighted issues such as trust, expectations, experience, satisfaction, etc., which are significant in studies concentrating on chatbots and associated interaction concerns (Sharma et al., 2022). Exploring the use of chatbot in varied educational setting and evaluate its functional use remains a relevant area for AIEd research.

2.5 21st Century skills in education

2.5.1 21st century skills

21st century skills are the abilities and educational dispositions that educators, corporate leaders, academics, and government agencies have identified as essential for success in 21st century society and workplaces (Voogt & Roblin, 2010). Some examples of 21st century skills are – critical thinking, technology literacy, collaboration, communication, leadership, creativity and so on. A sub-set of these skills have always been crucial for the students, but they are even more so in today's information-based economy. This idea is part of the growing international trend that focuses on the skills that students must master to flourish in a digital culture that is rapidly evolving. The contemporary workforce is far more likely than previous generations to switch careers or employment. Developing 21st-century skills is vital for preparing students for college, careers, and civic life. However, to provide students with a 21st-century education, adequate support structure in institutions is also required (Kaufman, 2013). There is also a corresponding need to integrate the 21st century skills at the curriculum level for having the desired outcomes (Gut, 2011).

The 21st century skills can be categorized in the following three dimensions: (1) Learning and innovation skills (2) Career and life skills and (3) Digital literacy (Fadel, 2008). This framework is often referred to as the P21 framework for 21st century learning. The P21 Framework for 21st Century Learning was established with input from educational experts, educators and business leaders in order to identify the knowledge, skills, and expertise that students need to be successful in their careers, lives, and citizenship (Mishra & Kereluik, 2011). There are other alternative frameworks also existing that characterize 21st century skills. For example, the Organization for Economic Cooperation and Development (OECD) in their 2009 working paper listed information literacy, creativity and innovation, problem solving, decision making and media literacy as some of the key 21st century skills (Ananiadou & Claro, 2009). Whereas the European Union (EU) has listed skills such as – digital competence, technology and engineering, literacy competence, mathematical competence, cultural awareness and citizenship competence as being important in the coming years (EU, 2018). One of the common reoccurring skills that is rated consistently important for the future is digital competence or digital skills. As economies in different parts of the world shift from being based on industry to being based on services, citizens need specific professional skills and mastery of other generic skill sets, with a focus on digital literacy.

2.5.2 Digital skills

The term digital literacy or digital skills does fall under the larger umbrella for the concept of 21st century skills. However, the latter is used to refer to a broad range of skills necessary to thrive in modern day work environment and knowledge society while the terms such as digital competences, digital skills, e-skills and digital literacy are underpinned by the use of ICTs (Van Laar et al., 2017). In the aftermath of the Covid-19 pandemic, the rate of digital transformation accelerated even further and many of the operational modes of business and education changed irreversibly. The general transition to digital-first interactions, such as virtual collaboration and remote work, has made digital skills more important than ever before to businesses and the workforce. While this evolution has resulted in beneficial effects like as improved labour mobility and the removal of geographic barriers to talent acquisition, it has also resulted in the widening of an already significant skills gap. Not only the digital skills are required to embrace these transitions and are key to secure career options in the future, the possession of these abilities is also critical to various firms and organization's survival.

The digital skills of an individual evolve over time. These skills are acquired in formal learning settings as well as informal and social use of technologies over time and through peer learning (Leahy & Wilson, 2014). Several conceptualizations have split the digital skills to more specific abilities. However, most of the interpretations remain limited to describing them in relation to information retrieval and technical aspects of their usage. Increasingly, researchers are stressing the importance of adding content creation and other skills for describing digital competences (Van Deursen et al., 2014).

Ferrari (2012) defines digital competence as a combination of information, communication, content creation, and problem-solving skills. Content creation, in this context, can be defined as the ability to create content in a variety of formats, platforms, and contexts. Whereas Helsper and Eynon (2013) classified digital skills into four major categories: technical, critical, social, and creative. Their categorization is based on the media literacy research, which states that the digitals skills should be tested beyond merely the technical level and in connection to the ability to operate ICTs for social goals. Van Deursen and Van Dijk (2009, 2010) measured the digital skills in four dimensions: (1) operational, "the skills to operate digital media" (2) formal, "the skills to handle the special structures of digital media such as menus and hyperlinks" (3) information, "the skills to search, select, and evaluate information in digital media"; and (4) strategic, "the skills to employ the information contained in digital media as a means to reach a specific personal or professional goal". Van Dijk and Van Deursen (2014) recently extended this framework by including communication and content creation skills. In this regard, Helsper et al. (2020) developed a validated scale known as Youth Digital Skills Indicator (yDSI), a cross-nationally validated measurement tool with 31 items dispersed among digital skills and digital knowledge questions, suitable for large-scale population research. The scale measures the digital skills of responding student along four dimensions – (1) Information navigation and processing skills (2) Content creation and production skills (3) Technical and operational skills, and (4) Communication and interaction skills.

2.6 Theoretical discussions and summary

As the profile of seafarers would evolve due to effects of the 4th industrial revolution, it would require adaptation in MET, to equip them will skillset to work in the complex operational environments. Some fundamental questions therefore arise in the backdrop of this anticipated climate. It would firstly be important to determine the new competencies necessary to prepare the future maritime workforce. There are several ways in which the concept of competence is often defined in the literature. However, in the reference of present work, it is important to tie the competence to education and real-life scenarios. The new competencies should reflect the increasing digitalized environment of shipping, to be able to align with the real-life context for which they are being defined. The pedagogical model currently employed for the training of seafarers include a combination of theoretical knowledge gained in academic setting and practical skills gained through apprenticeship. The continuing trend of automation and digitalization could cause changes in both these approaches. As digital environments require a different type of skillsets compared to their predecessors. This is equally applicable in the case of the formal regulatory requirements such as STCW provisions. In the context of navigators at an operational level for example, there are 19 competence themes and corresponding 66 Knowledge, Understanding, and Proficiency (KUP) items currently listed in the Table A-II/1 which would require revisitation with the changes in operations. It was noticed through the examples given by Jurdzinski (2018) and other general trends, that modern navigator is increasingly been required to perform supervisory duties because of increased information processing and decision support available on ship's bridge. However, merely introducing technological changes for efficiency concerns, without considering its corresponding impact on the job design and adaptability of the navigators can have detrimental effect on the balance of human, technological and work organization factors within the ship's bridge. Automation has a general tendency to make the repetitive aspects of the job tasks redundant. Therefore, certain competence requirements can become obsolete because of more accurate and reliable technological aids replacing their role. A recent example of such changes was the introduction of integrated navigation system and ECDIS on ship's bridge. As a result, the navigators were required to be proficient in the use of new digital systems for the purpose of navigation. In the event of further changes in technology related to maritime navigation, certain additional technical competence requirements would be required from the navigators as a consequence. Furthermore, the evident strength of the human operators in these complex systems onboard will be their adaptability and creativity (Ahvenjärvi, 2016). Thus, an investigation of non-technical skills for maritime operations would also be required. Non-technical skills can be described as social and cognitive skills that are required in addition to the technical skills to safely execute operations in the complex socio-technical systems (Flin et al., 2008). Examples of non-technical skills are –

decision making, leadership, situational awareness, and team work to quote a few. An understanding of novel technical and non-technical skills necessary for seafarers therefore could aid the MET community to prepare the future maritime workforce. These revised skillsets should be considered in the training and assessment framework of the seafarers. Failure to account for these changes could lead to similar challenges as described by Ghosh et al. (2014), i.e., a decontextualized nature of assessment of skills, where the lack of alignment between what is expected from seafarers versus what they are being trained and assessed, ultimately leading to a significant safety risk.

The generic 21st century skills will also play a key role in vocational education and training in the coming years, as they form the foundation over which subsequent specializations takes place. The trainees who will enter the workforce in the coming years should possess 21st century skills as recognized by P21, EU and OECD. Some examples of these skills were given as - communication, collaboration, decision making, creativity, digital skills and so on. In this regard, digital skills and competencies are considered particularly relevant for the occupational fields, due to advances in digitalization that are occurring in various professions. For the 21st century worker, digital skills will be alongside skills such as numeracy, communication, and literacy as the fundamental skills necessary for labour force. The maritime trainees would require proficiency in digital skills to utilize the increasing distributed modes of learning being available. As was noted earlier, due to introduction of distributed learning solutions in the form of e-learning, cloud simulators, VR simulators and similar, the trainee seafarers are able to pursue self-directed form of learning. Further use of these solutions enabled by ICTs will allow them to pursue life-long learning and transition through various roles in the evolving work domain. These factors constitute the macro-context related to the education and training of future maritime workforce which require consideration.

The role of instructors in vocational education and training is influential. It would be impacted with technological changes. The fundamental duty of instructors is expected to transition from those who impart the necessary knowledge to the ones who will facilitate learning (Maclean & Lai, 2011). As in all vocational education and training environments, the MET instructors play an important role in preparing the future seafarers. However, in the increasingly technology-rich learning environments, it is important to consider their professional development and use of digital tools. For the MET instructors to actively facilitate the learning process, firstly they would need to feel confident in their own ability in use of web 2.0 tools. It is therefore apt for the MET stakeholders to focus on the level of technology proficiency of MET instructors, to identify areas of potential improvement. The topic concerning professional development of the MET instructors is raised by Muirhead (2004), Vujicic et al. (2022) and Gamil (2008) among others, in their investigations. Muirhead (2004) elaborated upon the multimedia technologies available for the MET institutes and the need for instructors to be appropriately trained in their use. Whereas Vujicic et al. (2022) described various factors effecting the instructor’s competencies and their preparedness in light of current industry demands. Similarly, Gamil (2008) discussed the competitiveness of the instructors and its impact on the quality of education through a survey of various MET stakeholders. However, more specific discussions regarding how the instructors can integrate the various web 2.0 tools available and the opportunities now offered through the advent of AI was observed to be yet not explored in the research literature related to MET.

The increasing adaptation of AI in education presents an interesting avenue for further exploration for MET. When considering some of the technology integration frameworks commonly deployed in education, such as SAMR, RAT or TIM, at the most elementary level, the technology is merely described as supplanting the existing tools and practices. For example, In SAMR, the first level is termed as substitution, comparable to the term Replacement in RAT, and Entry level of TIM. However, AI technology, due to its fundamental nature, can target the highest levels described in these frameworks, such as Redefinition and Transformation. In the micro-context of learning environments where close interaction between instructors and students takes place, the Natural Language Processing (NLP) characteristic of AI is particularly impactful. NLP allows for the computers to process the queries and commands from humans and communicate to a certain extent in their own language. It can recognize context of the conversation and respond with pre-programmed dialogues. When utilized in the form of a conversational agent or chatbot, it can thus assist the instructors cognitively, by taking over the repetitive aspects of classroom interactions. The conversational agent or chatbot can also promote self-directed and personalized form of learning, as it responds according to the user queries. As it supports ubiquitous learning in remote devices, it can be characterized as one of the distributed learning solutions.

All the technological affordances should be considered in light of existing educational theories. The educational theories described earlier such as – behaviourism, cognitivism, constructivism, social-cognitivism and social-constructivism, are not mutually exclusive. Some of them are inter-related with agreements on various tenets. They can be thought of as various lenses, used to describe and analyse the learning process happening in any educational environment. For example, social constructivism and social cognitivism, both highlight the importance of social environment to the learning process. Constructivism and social constructivism are similar in their conceptualization, with a focus on the learners being active constructors of their knowledge. The Social-cognitivism theory espouses the view of classical and operant conditioning of behaviourism, while also agreeing with the information processing aspects of cognitivism. Each of these theories have relevant application in the modern, increasingly digital learning environments. For example, behaviourism can influence the gamification of learning, whereas cognitivism can assist in determining the adequate level of information load that should be presented to the learners. Constructivism and Social cognitivism has potential use in e-learning and immersive environments, with individual or group level participation. In the present research, for the purpose of presenting proof-of-concept regarding application of AI to MET, social constructivist learning perspective was utilized. Social constructivism as described by Vygotsky (1978) emphasizes the fact that learning process takes place in social interactions with peers and instructors before being internalized by the student. As noted earlier, due to advances in ICT, distributed learning solutions are being increasingly adopted which enable new modes of learning which are both self-directed and group oriented. This is in line with learner-centred social-constructivist perspective. Furthermore, co-construction of knowledge is facilitated in these modes of learning, due to ease with which virtual artefacts can be created and shared. Considering these aspects of theory and interaction possibilities due to NLP, an AI chatbot was conceptualized. The chatbot was designed to act as the More Knowledgeable Other (MKO) in the learning activities, which could facilitate the scaffolding process as described in Figure 7. The research literature reviewed above therefore guided the theoretical stance in the thesis and sheds light on the key prevalent trends related to the empirical investigation.

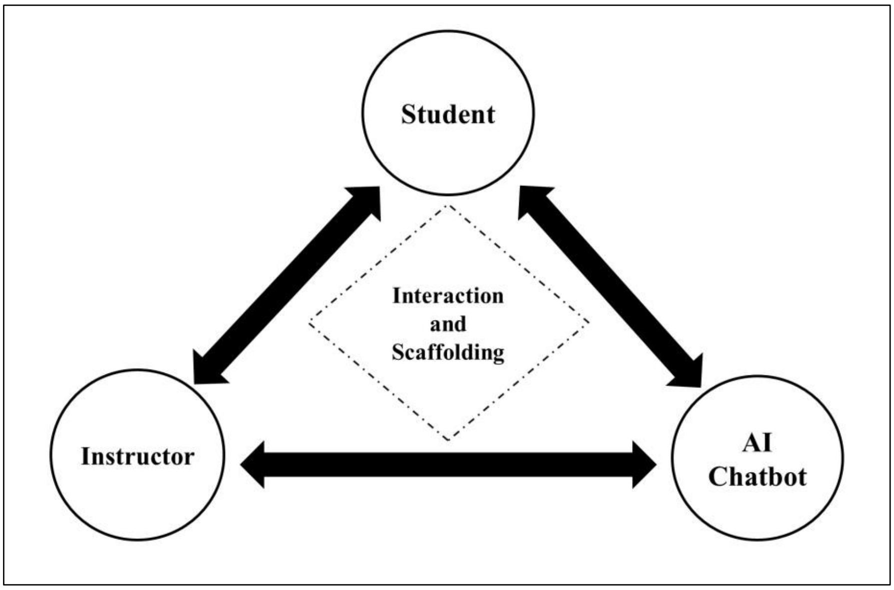

Figure 7. The Role of AI Chabot in learning

The theoretical insights presented in this section illustrated the frameworks that guided the data collection in respective studies constituting the thesis and the overall research objectives. The next section presents and describes the methodology of the thesis.

3 Methods

The research methods can be described as an investigation strategy which helps the research to progress from theoretical ideas to tangible research designs, collection of empirical data and its analysis. For conducting research studies and projects, it is important to clarify the philosophical reasons, underlying assumptions and overall worldview of the principal investigator which may have an impact on how the research work was executed, which instruments were utilized and the interpretation of the generated knowledge. Firstly, the ontological, epistemological and methodological stances are clarified.

3.1 Ontological, epistemological, methodological reflections

3.1.1 Review of philosophies and their connection

Three interrelated branches of philosophy that are frequently used in academic research are ontology, epistemology, and methodology. Together, they form the concept of the research paradigm. The term "research paradigm" refers to a set of norms, standards, and guiding principles that are used in the scientific and scholarly communities (Olsen et al., 1992). There are different versions of their definitions depending upon the disciplines. In simple words, Ontology refers to the nature and structure of reality. Ontology as a philosophy, deals with how one views the world and what assumptions we make about its nature, independent of any other considerations. As an example, it is perfectly acceptable to study the ontology of fictional entities, as long as they have some defined characteristics agreed upon by a set of individuals. Gruber (1993) defined ontology as an "explicit specification of conceptualization". Similarly, Borst (1997) defined it as "a formal specification of conceptualization". The central point to consider in these definitions is that the conceptualization is shared by a number of individuals as referred above. Studer et al. (1998) combined these two definitions and defined ontology as "a formal, explicit specification of a shared conceptualization". Conceptualization in this context refers to a body of knowledge with its entities, objects and the inter-relationship between them (Guarino et al., 2009). From an ontological perspective, there are two versions of reality which are labelled as Realism and Relativism (Killiam, 2013, p.17). The realism belief pertains to the fact that there is an absolute version of reality independent to any context or point of view which can be measured and quantified. In contrast, the relativism belief states that there are multiple versions of reality dependent on the point of views which can only be understood through language and discourse (Bilgrami, 2002). Broadly therefore, the realism belief tilts towards use of quantitative approach to gathering empirical data, whereas relativism belief is about analysis of qualitative data. The choice of ontological belief will have a subsequent impact on the selection of epistemology and methodology employed in answering the research objective (Guba & Lincoln, 1994).

The study of validity, scope, and methods of acquiring knowledge is known as epistemology. The topic of epistemology is important because it influences how scholars structure their study in their pursuit of knowledge (Moon & Blackman, 2014). It addresses issues such as a) what constitutes a knowledge claim; b) how knowledge can be gained or created; and c) how to assess the extent to which it is transferable. Epistemology is often referred to as the "theory of knowledge". The validity, variables, and methodologies of acquiring knowledge are all part of epistemology. Examples of epistemological or practical knowledge could be - knowing the probability of rain tomorrow or knowing how to identify music from an artist. Methodology whereas refers to the specific approach of data collection selected by the researcher. Methodology depends upon the ontological and epistemological position held by the researcher and can be of qualitative, quantitative, or mixed design in nature. Some examples of the commonly employed methodologies in social science research includes but are not limited to – experimental/quasi-experimental, survey, causal-comparative, ethnographic, case study, grounded theory, content analysis and action research. The following Figure 8 can illustrate the relationship between ontology, epistemology, and methodology in a research endeavour. Together, the ontology, epistemology, and methodology describe the concept of research paradigm which similarly deals with the constitution of knowledge. There are three main types of research paradigm understood by practitioners in social science research: (1) Positivism (3) Constructivism and (3) Pragmatism (Jupp, 2006). Positivism paradigm holds the view that knowledge is objective. Positivism paradigm stresses on the importance of the hypothetico-deductive model of knowledge generation (Park et al. 2020). It is often related to a deductive approach in research studies. Another version of positivism paradigm known as "post-positivism" also exists in social sciences, which is based on acknowledging the limitations of the positivism paradigm (Phillips, 1990).

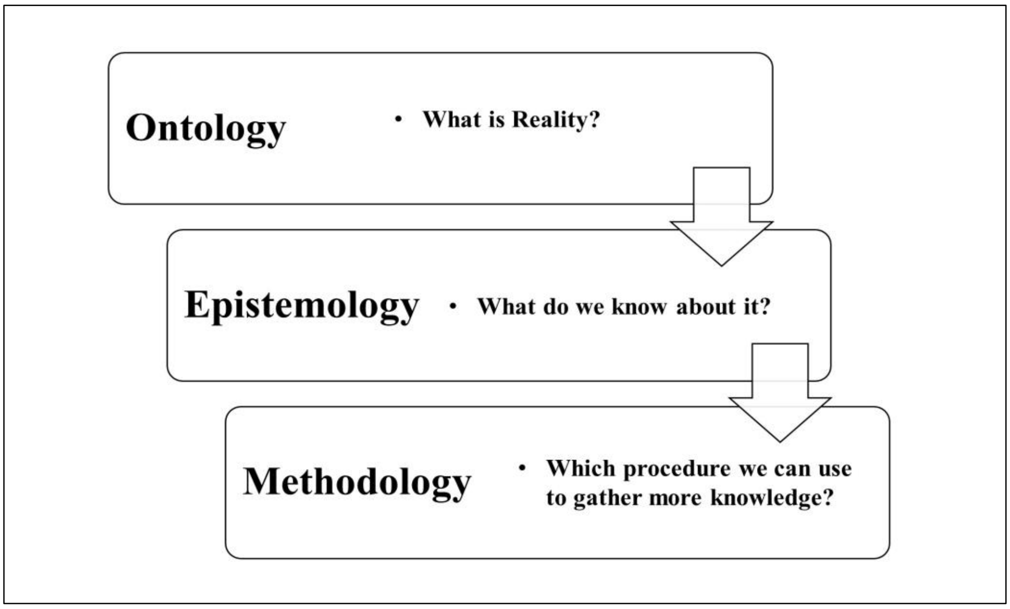

Figure 8. Relationship between Ontology, Epistemology and Methodology

The post-positivists state that the reality as observed cannot be free from subjective biases and we should understand the role of social contexts and arrive at the approximation of truth. Constructivism paradigm, on the other hand, purports the inter-subjective and contextual nature of knowledge. In this paradigm, importance is given to inductive nature of extracting facts and themes associated with research query. Constructivism is related to the philosophy of interpretivism. While constructivism is concerned with production of knowledge jointly, interpretivism deals with understanding shared perspectives and meaning making. The constructivists understand the nature of reality from a subject's own perspective and seek to bring forth various perspectives within a social context. The term constructivism can have different meaning if used in domains like education or psychology than in philosophy. Finally, the pragmatism approach considers both aspects in the knowledge generation process and utilizes a different approach to achieve research objectives. In essence, pragmatism steers away from the discussions surrounding the nature of reality and concentrates on practical understanding of the research problem (Patton, 2005, p.153). Further, the pragmatism philosophy rejects sharp dichotomies, rather it embraces falsifiability and antiscepticism (Putnam, 1995). Pragmatists believe that the there is value in generating solutions for research problem that function well in the local context than in theoretical level. In pragmatism paradigm, the focus is therefore on the interplay between belief and actions through and active process of enquiry and the researcher is interested in extracting actionable knowledge (Morgan, 2014).

3.1.2 Paradigm adopted in this project

The knowledge generated in a research project is often influenced by the worldview and philosophical assumptions of the researcher. Considering the theories discussed in the above section, the research paradigm which was primarily utilized in the thesis was post-positivism. However, the study also has footprints of pragmatism in its conception. Pre-dominantly a quantitative approach to research design and data collection was utilized. Quantitative research employs questionnaires, surveys, and experiments to collect data, which is then reworked and tabulated in numbers, allowing the data to be usually characterized through statistical analysis. This is in congruence with the ontological perspective of realism. Despite this, a purely positivist stance was difficult to achieve in the context of this project. Due to the global nature of maritime industry and wide differences in educational practices of various states, it would have been not feasible to design survey studies and experiments for extracting knowledge which is applicable in all parts of the world. Qualitative research on other hand, utilizes observations, interviews, focus group discussions and so on, to collect textual data about various perspectives, meaning making and perceptions. A more qualitative approach to collect data could have been useful with some potential of getting rich insights about the research problem in question. However, this approach was deemed to be resource intensive for collecting large amounts of data that could inform level of skills for instructors and students. I acknowledge these limitations and therefore was interested in exploratory studies assessing various facets of technology integration and competence mapping with utilization of standard scales to limit subjectivity. This approach provided the most practical solution for attempting to tackle the research problem within the constraints of time and resources. Therefore, a post-positivist stance with some elements of pragmatism was adopted. In first study, there has been open ended qualitative questions posed to gather qualitative data regarding novel competence requirements, after which relevant competence themes were extracted. This approach utilized the inductive methodology for themes extraction. Except this instance, all the data collected has been in the form of closed survey questionnaires with Likert type scales. the responses given by the participants were quantified and synthesized. This is line with a deductive methodology to arrive at empirical findings. Descriptive and inferential statistics of various variables for each study were obtained.

3.2 Data collection and analysis

3.2.1 My background

To elaborate further on context of the research and my motivation to conduct the project it is also important to briefly describe my professional background. I am also a product of Maritime Education and Training domain with my primary competence as a navigation officer. I hold a Bachelors in nautical science and sea experience spanning seven years. I decided to pursue higher education and subsequently completed a Masters in maritime management with technical specialization. During this phase, I also became involved with some of the educational projects related to the department of maritime operations at University of South-Eastern Norway, where I also worked as graduate research assistant. Subsequently, I received fellowship for the PhD project with a focus on Maritime Education and Training. Therefore, my background and orientation did play a part in selection of the research topic. It allowed me to frame research objectives which could have been difficult for an outside enquirer of the topic. However, as a part of the PhD journey it was also imperative of me to acquire a deeper knowledge on research methodology which can form a toolkit for carrying out intended work. As a part of the educational component of PhD project, I got the opportunity to attend courses on quantitative research methodology and acquired knowledge related to statistical analysis. The knowledge related to qualitative research methodology was acquired by being part of the Training and Assessment Research Group (TARG) and while collaborating on various research articles in a support capacity. Additional knowledge on topics such as use of Data Science and Artificial Intelligence was gained through specific online courses. Furthermore, during the final few months of empirical data collection, I also worked with *TERP AS*, an educational technology company situated in Norway with a focus on Maritime Education and Training products. I had some experience in instruction with responsibility of subject manager in one of the courses at master’s in science program within my department at the University of South-Eastern Norway. I gave lectures on Research Methods course, in addition to delivering guest lectures on the topic of human element in the shipping. Furthermore, I got the opportunity to supervise master students on theses related to Maritime Education and Training during the PhD project.

3.2.2 Data collection

The primary data sources for the research studies were professionals in the MET industry, instructors, seafarers, and students. The thesis utilized survey questionnaires to collect data. The collected data was pre-dominantly quantitative in nature with one instance of qualitative open ended survey questions. The respondents in the studies were selected through purposive sampling. The online purposive sampling techniques has recently emerged as a method of choice for social science researchers aiming to gather data about well-defined groups with specific socio-cultural context. They provide data in a timely and economical manner for the purpose of analysis. However, random sampling techniques still have the higher standard in comparison due to absence of researcher bias and better generalizability. The researcher should be careful in drawing inferences when using purposive sampling techniques (Andrade, 2021). These limitations are duly acknowledged in all of the individual research studies conducted. The scope of the studies were defined throughout the papers. The recruitment method for the respondents in the study was through professional network of the researcher and the affiliated university. There were some elements of randomness in sampling, as in each of the studies except paper-3, a digital link was generated and was distributed to both the contacts of the researcher and online professional groups. In the latter case, it was not in the control of the researcher which qualified respondents opted to answer the questionnaires. Nonetheless, as a heuristic, most of the responses can be described to be collected in a non-random manner.

In paper-1, the intention of the study was to analyse the suitability of STCW competence regulations for hypothetical advanced maritime operations involving autonomous ships. The generated questionnaire using Qualtrics© was distributed in several digital platforms. The respondents for the study were maritime professionals which comprised all the geographical areas. Further, some demographic data regarding their designation, specific area of shipping, years or experience and educational levels were collected. A total of 109 valid responses out of 153 obtained responses were included in the analysis. In paper-2, the study was concerning measuring the technology proficiency levels of maritime instructors. In this study, a validated scale known as Technology Proficiency Self-Assessment for 21st century (TPSA-C21) was utilized in addition to a unidimensional scale measuring the technology level of use as per the Concern Based Adoption Model (CBAM-LoU). The questionnaire was digitalized using the Nettskjema© tool and similarly distributed as in earlier study, using an online purposive mode of gathering responses. However, the scope was defined as respondents who work as MET instructors in Europe. Further demographic data regarding their educational qualifications, gender and years of experience was collected. Similarly, in paper-3, the scope of study was narrowed down to the 2nd year B.Sc. in nautical science students of the affiliated university. A total of 18 students participated in test of the developed AI Chatbot for the purpose of COLREGs training. The validated scale known as System Usability Scale (SUS) was utilized for gathering the data regarding usability of the AI Chatbot. In this study, demographic data such as Gender, their prior experience with COLREGs and interaction with Chatbots were deemed important to provide complete context. In both paper-2 and paper-3, the data was analysed to see if there are differences in obtained responses due to demographic grouping. In paper-4, the intention of the study was to assess the level of digital skills of maritime trainees. The scope was narrowed to include respondents from the Philippines, which is a major skilled maritime workforce supplier nation. The professional network of the industrial partner of the thesis, namely *TERP AS*, were utilized to disseminate the digital version of yDSI (Youth Digital Skills Indicator) scale. Again, the Nettskjema© tool was utilized for this purpose. The demographics data such as Gender, Educational discipline and Age was gathered. The responses were collected in online purposive sampling approach with a total of 234 valid responses collected out of total 270. The Table 1 below summarizes the data collection and analysis approach for all four studies.

Table 1. Empirical data collected and the methodology employed in the thesis

Paper	**Approach**	**Methodological tools**	**Analysis method**	**Number of participants**
1	Mixed methods	Survey Questionnaire	Descriptive statistics Exploratory Factor Analysis Thematic Analysis	109 maritime professionals

2	Quantitative	Survey Questionnaire	Descriptive statistics Inferential statistics	62 MET instructors
3	Quantitative	Survey Questionnaire	Descriptive statistics Inferential statistics	18 B.Sc. students
4	Quantitative	Survey Questionnaire	Descriptive statistics Confirmatory Factor Analysis	234 B.Sc. students

3.2.3 Survey instruments

As mentioned earlier, the survey questionnaires were used to collect the data in the thesis project. The advantages of using questionnaires are mostly related to their ability to collect good number of data points economically and quickly. Further, the data obtained in numerical mode makes it easier for visualization and analysis using various tools. Some limitations related to using questionnaires are their limited response rate and inability of the researcher to probe further insights from the respondents. The thesis utilized the following survey questionnaires:

- Technical and Non-technical competence questionnaire derived from the STCW table A-II/1 and literature review related to additional relevant skills that could be suitable for future navigation officers.
- The Technology Proficiency Self-Assessment for 21st Century (TPSA-C21) scale *(Appendix A6)*
- Concern Based Adoption Model - Level of Use (CBAM-LoU) *(Appendix A7)*
- The System Usability Scale (SUS) *(Appendix A8)*
- The Youth Digital Skills Indicator (yDSI) *(Appendix A9)*

3.2.4 Data analysis

As the research paradigm was post-positivist and pragmatic in nature, most of the data analysis involved statistical calculations of the parameters in various dimensions depending on the questionnaires used in the study. It was also coupled with inductive analysis of emergent themes from the qualitative data. Quantitative data analysis can be described as a process of manipulating and evaluating numbers in order to extract meaning from them which can then be utilized to answer research questions, test hypotheses, or explore causal relationships (Albers, 2017). Quantitative data analysis can further be divided into descriptive and inferential statistics. The descriptive statistics is helpful in obtaining the summary of the collected data and characteristics of the different variables, whereas the inferential statistics allows the researcher to test relationships between the variables and draw inferences from it. Qualitative data analysis on the other hand involves the process of data collection, sorting, coding, breaking it down into manageable chunks, synthesis, and searching for patterns (Bogdan & Biklen, 2003). In both cases, it is first imperative for the researcher to sort and prepare the data for analysis. All the collected data during each of the research studies was first captured in an MS Excel© Comma

Separated Value (CSV) format. Afterwards, data cleaning and preparation process was conducted. For qualitative data that meant the aligning of obtained textual data with each respondent uniformly, whereas the obtained quantitative data checked for straight lining or missing responses. These responses where applicable were removed from the data set before it can further be analysed using advanced software packages such as - IBM SPSS© and SmartPLS©.

In paper-1, in addition to obtaining the descriptive statistics for the Knowledge, Understanding, Proficiency (KUP) items from the STCW Table A-II/1, an Exploratory Factor Analysis was conducted, which resulted in a factor structure with new competence themes. Exploratory Factor Analysis (EFA) is a method of multivariate statistical analysis used in quantitative studies. It simplifies large amounts of data by breaking it down into a fewer number of factors that form groups of related variables (Kilner, 2004; Tabachnick et al., 2007). EFA enables researchers to perform deductive analysis, theorize, and assess the measurement instrument's construct validity (Williams et al., 2010). In addition, the indicators' consistency, convergent validity, and divergent validity were examined by using the partial least squares structural equation modelling technique for measurement model assessment, as outlined by Hair et al. (2019; 2020). The descriptive data was also collected for non-technical skills and the open-ended questions in the survey instrument were examined through qualitative thematic analysis.

In paper-2, the descriptive statistics regarding the score of MET instructor on each of the 34 items constituting the TPSA-C21 scale were obtained. These scores were further checked for variance in response because of demographic groups with different levels of experience and educational qualifications were checked by the use of non-parametric Kruskal-Wallis ANOVA test. Basically, there are two types of inferential statistics tests – parametric and non-parametric. The latter technique is helpful when condition of normality of the obtained sample is not perfectly satisfied due to limited sample size. It was utilized in both paper 2 and 3. Finally, a frequency percentage distribution of each of the Concerns Based Adoption Model (CBAM) – Levels of Use was illustrated to give an idea of which stage of technology integration MET instructors most identify with currently.

Similarly, in paper-3 the data which was obtained regarding the student user experience with AI Chatbot was analysed using descriptive statistics as well as non-parametric Mann-Whitney U tests. This test is similar to the Kruskal Wallis test and can be thought of as belonging to its sub-set of statistical tests used when condition of normality is not satisfied due to limited sample size and variance in the distribution of data points. The usability of AI chatbot as a whole was also calculated from the System Usability Scale (SUS) by following the guidelines given by Brooke (2013).

In paper-4, the descriptive statistics were tabulated for the scores received by the students for each of the items of the Youth Digital Skills Indicator (yDSI) scale. These were illustrated in the form of percentage frequency distribution to give an idea of relatively how much the students felt confident in their digital skills. Furthermore, a Confirmatory Factor Analysis (CFA) was carried out. The CFA is a multivariate statistical technique used to evaluate the structure of an instrument by checking the validity and factor loadings of a number of measured variables. By obtaining the fit indices and checking the covariance of the factors, it is used to assess the theoretical structure of the instrument (Brown & Moore, 2012).

3.2.5 Notes on Reflexivity

After briefly describing the data collection & analysis process and my own professional background, it is important to further discuss my own role as the researcher and position myself in the above-mentioned methodological process. Reflexivity is important consideration to address in contemporary social science research and more specifically when dealing with qualitative data. Reflexivity can be defined as "*the constant awareness, assessment, and reassessment by the researcher of the researcher's own contribution/influence/shaping of intersubjective research and the consequent research findings*" (Salzman, 2002, p.806). The basic premise in discussing reflexivity is related to the interpretivist paradigm position that the reality and knowledge is influenced by human inter-subjectivity. There are many instances in the methodological phases of the studies which can be influenced by my position as the researcher. In most of instances, I took the decision to obtain the responses from the participants from the studies through survey questionnaires. While this approach does remove some subjectivity in the collected data, it can also be thought of as being too deductive. For instance, there is no possibility of considering different interpretation of the survey questionnaires by each of the respondents and the results often indicate a net response from all of the participants. Additionally, this approach does not provide the opportunity to the researcher to include the respondents actively in interpreting the meaning behind their given responses. However, even in quantitative analysis like – Exploratory Factor Analysis (EFA), the naming of obtained factors is a subjective process. In this process of generating novel competence themes from the obtained data, I am also introducing my subjectivity in the results to a certain degree. For the collected qualitative data, during the thematic analysis process, the naming of emergent themes was also a subjective process. These assigned themes also to a certain extent were result of the relevant literature I consulted and therefore were a function of my own worldview. Finally, it is also important to acknowledge the role of organizational factors in the research project which influenced its trajectory. The project was funded by the affiliated university as an attempt to contribute towards Maritime Education and Training research as a part of their strategic objective. The researcher and stakeholders involved in the process have also shaped it in terms of research objectives, methodology adopted and dissemination efforts. A brief description of the role of other researchers than myself which supported the achievement of research objectives are described in Appendix A6.

3.2.6 Reflexive thematic analysis

In addition to the generic analysis process described above, it is necessary to specifically discuss the process of thematic analysis in a greater detail than explained above due to the qualitative nature of this sub-set of collected data and its analysis. The thematic analysis method was originally proposed by Braun and Clarke (2006) as a flexible and intuitive approach to analyse the qualitative data. It consists of six steps – (1) Data familiarization (2) Initial code generation (3) Generating themes (4) Theme review (5) Defining and naming themes and (6) Report production. The term thematic analysis is prefixed by the original proponents with the word "reflexive" to highlight the need for the users of the technique to engage their data and realize their own biases and positions when conducting qualitative research. Another reason for using the term "reflexive" as a prefix was to delineate their approach from other two types of thematic analysis. According to Braun et al. (2019a), thematic analysis can be divided into three types – (1) coding reliability approach (2) codebook approach and (3) reflexive approach. They further elaborate that coding reliability approach can be described as positivist approach within qualitative paradigm, which utilizes pre-defined and structured codes, and the focus is given towards inter-rater reliability statistics when analysing data with less room for interpretation. Whereas, the codebook approach is more interpretivist, still relying on a defined initial structure to analyse the qualitative data. In contrast, the reflexive thematic analysis is "organic" which uses the subjectivity of the researchers as a "resource" (Braun & Clarke, 2021a). Reflexive thematic analysis is therefore viewed as theoretically flexible method for developing, analysing and interpreting patterns in the qualitative data set (Braun & Clarke, 2021b, p.4). Despite being viewed as a flexible and organic approach, it is still considered a necessary part in the methodology to explicitly describe the steps taken to analyse the data and arrive at the results. It should further be noted that these steps of reflexive thematic analyse are not strictly linear, with the possibility and common occurrence of iteration in between.

(1) Data familiarization: The process of data familiarization began with organizing of the collected data from the survey platform website to a MS Word document and arranging them in a sequential manner. In total there were three opened ended question which were asked to the respondents, such as – Which additional technical/cognitive/social skills do you think would be important in the future? Therefore, three distinct clusters of qualitative data were obtained. There were a total of 77, 45 and 39 responses in textual format for these open-ended questions, comprising a total of 2378 words. As can be seen, not all the respondents out of 109 who filled the quantitative part of the questionnaire, chose to answer the open-ended qualitative part.

(2) Initial code generation: After arranging the data in an organized manner, I went through the data together with the co-author of paper-1 and we read each of the textual responses line by line. The interpretation of the textual responses were done in an "inductive" manner, as the questions were open ended, and we were looking for additional novel skillset that would be required under each of the three categories. It is essential to clarify that "inductive" approach in reflexive thematic analysis does not imply pure induction. Reflexive thematic analysis cannot be conducted in a theoretical vacuum and prior paradigmatic, epistemological and ontological assumptions usually are applicable (Braun & Clarke, 2021a, p.331). These initial codes were separately noted in a digital notepad.

(3) Generating themes: After the initial code generation from the long lines of textual data, the shorter clusters of synthesized data were again organized into MS Word document using bullet points. The broad outline of what can be termed as "sub-themes" started to appear as a function of our interpretation at this stage. There were instances of repetition in code, and they were correspondingly clustered under same headings. As noted above, although the process was inductive, not all codes were included in the next stage. As the focus was on novel skillsets, those codes that just repeated existing skills already codified under STCW table A-II/1 or explicitly mentioned in the reviewed literature for paper-1 were not considered.

(4) Reviewing, defining and naming themes: After removing the redundant codes and obtaining the broad overview of lower-level sub themes, an iterative process followed with co-author of paper-1 where the set of codes were scrutinized and reviewed. In this step, care was taken to connect the themes and sub-themes with initial theoretical framework while not adding redundant skillset. The process involved deliberation and negotiation between both researchers regarding appropriate thematic titles. The relevancy to the original open-ended questions was again verified. Furthermore, this process also involved visualization of themes and sub-themes through diagrams in MS Word document.

(5) Report production: After finalizing the title of themes and their visualization in a structure. The report was produced by the principal investigator. The visualization of themes under separate figures aided this process. Eventually total of two corresponding figures were also constructed. In total, five themes related to technical skills were identified. - IT skills, safety and security management skills, knowledge of engine room operations, electronic equipment, and system integration. With respect to non-technical skills the eight novel themes were listed as - non-routine problem solving, self-regulation capacity, critical thinking, mental readiness, systemic thinking, the ability to develop trust in teams, the ability to adjust to cultural differences, and negotiation abilities.

3.3 Reliability, Validity and Ethical considerations

Reliability, validity and ethics are important concepts in research methods because they determine the quality and accuracy of the results obtained. The term reliability refers to the consistency and stability of results over time and across different measures or observations. If a research study is reliable, the results should be consistent if the study was repeated using the same methods. This ensures that the findings can be replicated and trusted. On other hand, validity refers to the accuracy and truthfulness of the results. It assesses whether the results truly reflect what they were intended to measure. For example, a valid study will measure what it claims to measure and will not be influenced by external factors. It is often debated that the concepts of reliability and validity refer to the positivist paradigm in research and are not transferable when evaluating qualitative data (Merriam, 1998). Therefore, a different framework for evaluation is utilized when discussing findings originating from the textual responses obtained in the first study. However, as a general practice, first the criteria for both types of data is described before describing the specific characteristics of quantitative and qualitative data. In this regard, Elliot et al. (1999) have given seven evolving guidelines which are common for evaluating both qualitative and quantitative research. They can be listed as – explicit scientific context, appropriate methods, respect for participants, specification of methods, appropriate discussions, clarity of presentation and contribution of knowledge. These guidelines can be discussed briefly to shed further light on the quality and analysis process of the data. To begin with, the scientific context of the research project has been described early on in the introduction section highlighting the motivation to undertake the research project. The scope of the project was situated in the topics such as STCW regulatory framework, the skill development for MET instructors, students, and the use of educational technologies such as AI in maritime learning contexts. The rationale behind selection of methodology was expanded upon in the present section of methodology. As described earlier, the reasons to narrow down on pre-dominantly quantitative survey questionnaires was given. The choice of methodology was influenced by post-positivistic beliefs held by the principal investigator, as well as practical concerns. The discussion section follows in the thesis where the implications of results are further elaborated upon and compared with parallel findings by other investigators where such results are available. By specifying each of the steps in the current body of texts as well as the research articles forming the thesis, every effort has been taken to ensure clarity of the research objectives, analysis process and the obtained results. Furthermore, recognized practices related to conducting survey studies while ensuring anonymity of the participants have been followed. In all of the studies, the participation was strictly voluntary, and the contact details of the principal investigator were always provided. Being the principal investigator myself, it is hard to evaluate the contribution to the larger body of knowledge that was ultimately made with these studies. However, as described earlier, it was observed that the research area which was the focus of this project had not been investigated before, therefore, it can be claimed that the studies did contribute to addressing an evident gap with respect to MET literature. Having described the general context of the project in terms of broad guidelines, certain specific parameters related to quantitative data are provided next. Firstly, the reliability and validity parameters of the survey data will be discussed which will be followed by steps taken to ensure quality and accuracy of the qualitative part of the survey data.

3.3.1 Reliability and Validity

The concepts of reliability and validity are central to the quantitative survey methodology of data collection primarily utilized in this thesis. The stability of a measurement scale, i.e., how far it will yield the same results on subsequent occasions, is referred to as reliability (or consistency), whereas the degree to which a scale measures what it is supposed to measure is referred to as its validity (Bannigan & Watson, 2009). There are different ways to assess the reliability and validity of the collected data for the surveys. For instance, the reliability is determined by measures of stability, internal consistency and equivalence, whereas, validity is determined by factorial validity, convergent/divergent validity, content validity and so on. In all of the studies carried out, the reliability of collected data was primarily measured by determining Cronbach's alpha. In paper-1 and paper-2, measures of composite reliability were also provided. Factorial validity using confirmatory analysis was primarily used in the studies (except paper-3) for ascertaining the validity of the collected data. In paper-1 and 2, measures of convergent and divergent validity were also given. Only reliability statistic was determined in the paper-3, since a 10 item unidimensional scale was utilized. (SUS). To describe some of the associated terms further, Cronbach's alpha is an index which is used to measure the internal consistency of a set of items, i.e. to which extent the items are measuring the same construct. It is therefore used to determine the reliability of a scale or set of items. Its value ranges from 0 to 1, where a value ranging 0.8 to 0.9 are usually considered good. Low values (<0.60) are not desirable as it would mean that the items are not reliably measuring the construct. However, high values (>0.95) are also not desirable as they indicate redundancy (Tavakol & Dennick, 2011). Composite reliability, on other hand, is a similar measure for assessing internal consistency. However, by considering the factor loading of the construct also into account, it is thought to be more reliable measure than Cronbach's alpha when measuring item reliability. Average Variance Extracted can be described as the average amount of variance explained by the various variables forming a particular construct (Farrell, 2010). Average Variance Extracted, sometimes taken together with Composite Reliability is used to explain the convergent validity of the constructs (Hair et al., 2019).

In paper-1, the Cronbach's alpha (CA) value for the factors ranged from 0.617 to 0. 880. The composite reliability (CR) values ranged between 0.828 and 0.925, which is considered "satisfactory to good" according to the recommendations given by Hair et al. (2019). Except for Factor 1, the obtained Average Variance Extracted (AVE) values were more than the required threshold of 0.5 (Hair et al., 2020). In paper-2, the CA values ranged from 0.814 to 0.920 for the factors. The CR values were between 0.871 to 0.939, whereas the AVE values were between 0.585 to 0.723 for the factors. In paper-3, as indicated earlier only CA value was determined for the unidimensional scale and it was found to be 0.884. It was above the 0.700 threshold generally considered acceptable for the scale with similar number of items (Nunnally & Bernstein, 1994). In paper-4, the CA values for the factors ranged from 0.849 to 0.910. The CR values were between 0.787 to 0.867. Notably, only 1 out of 4 factors in this study had an AVE more than 0.5. However, the CR values of all the factors were more than 0.6, which established the convergent validity as adequate for this study (Fornell & Larcker, 1981).

3.3.2 Quality Criteria for Qualitative data

Thematic analysis was performed on the qualitative data collected through the open-ended portion of the questionnaire to extract the most important themes. thematic analysis can be defined as "a method for identifying, analysing, and reporting patterns (themes) within data" (Braun & Clarke, 2006, p.79). In this context, a theme is a type of *patterned* response or interpretation that can be found in the data. Categories and codes were developed for the identified competence themes. As explained earlier, only the themes that were not already covered by the STCW competence framework for technical skills or the reviewed literature for non-technical skill requirements for navigators were qualified after the iterative coding process. For commenting further on the qualitative part of thesis, which was only a subset of paper-1, the guidelines given by Yardley (2000) can be used as a reference. According to Yardley (2000, p.219), there are four essential criteria for evaluating value in the qualitative data analysis, namely - (1) sensitivity to context, (2) commitment and rigour, (3) transparency and coherence and (4) impact and importance. The thesis attempted to demonstrate the sensitivity to context through a thorough review of literature related to the research objective of paper-1 as illustrated in the earlier sections. Furthermore, demographic data was also collected and tabulated in paper-1 to give more context to the readers. The elaboration of my own professional background and motivation to conduct research on Maritime Education and Training was further provided to explain the context more. However, it should be noted that due to impersonal method of data collection, it was not possible to engage with the respondents more than what could have been experienced through a more personal data collection method such as interviews. This can also be viewed as a positive alternative, as there were less chances of making the respondents conscious through personal presence of the researcher. The thesis attempted to demonstrate commitment and rigour by clearly outlining the data analysis process related to thematic analysis, as given in the earlier section. The data was analysed by the two independent researchers collaboratively with adherence to the guidelines given by Braun and Clarke (2006), in the attempt to demonstrate particular engagement and rigour in the analysis of data. This step, along with the literature review, also provided a reasonable level of transparency and coherence in the stated narrative, by giving the readers a walkthrough of the steps involved. Additionally, efforts have been made to describe the assumptions and worldview of the principal investigator as much as possible. Also, the relative narrow scope of the research study and the informed consent process was instrumental in addressing the transparency and coherence aspects of the research project. It is subjectively difficult to clearly assess the final criteria as stated by Yardley (2000), i.e., the impact and importance of the qualitative subset of data from paper-1. However, it can be argued that the process met the original research objective. Additional number of respondents could have been beneficial in further strengthening the last dimension of the quality criteria.

3.3.3 Ethical considerations

The thesis followed all the ethical guidelines as listed by the affiliated institution of the author. Most of the guidelines pertain to the principles of informed consent, minimising the risk of harm, and anonymization of the participant data. As such, no personal data was collected in the research studies which can directly be linked to individual respondents. In the instances, such data was collected, a prior Norwegian Centre for Research Data (NSD) form was filled and query for permission filled online. However, it was later anonymized after the duration of data collection and analysis expired. The respondents were notified about the nature of the study and their rights during the participation. This was done through a statement informing the nature of the project, assurance of voluntary participation and other relevant information which was provided to them before the study commenced. The participants were informed that they are free to withdraw in any stage during the data collection. Contact details of the principal investigator was also provided in every case. The extracts of these research intent declaration are also provided in the appendix (A1-A4). Where applicable, the Data Protection Officer (DPO) of the affiliated institute was involved and consulted with. In certain instances where established scales were utilized (TPSA-C21 and yDSI), the original authors of the related studies were contacted and consulted to better understand the procedures of the scale use and data analysis. The funding sources were clearly acknowledged in all the individual papers constituting the thesis. Where specifically asked by the journals, a declaration of no conflicts and individual contributions of the authors in the formulation of the manuscript was also described. All the research papers constituting the thesis are open access in nature and hosted in platforms like – ResearchGate© and USN Biblioteket (Library) for instance. In summary, all possible efforts to follow the ethical guidelines and open science initiatives were followed.

4 Results

This Chapter includes the summary of the key findings and results emerging from the thesis. A detailed description of the findings can be seen in the four appended papers. Through a pre-dominantly post-positivist and pragmatic stance, the thesis studied both macro and micro contexts of MET, along with the issue of the professional development of the maritime instructors. After the results, the findings are discussed in light of the research objective and theoretical framework, before articulating the key contributions, limitations and directions for further research.

4.1 Summary and key findings from paper-1

The purpose of paper-1 was to investigate the suitability of the existing STCW requirements in relation to the future autonomous operations and identify additional technical and non-technical skills that will be required of the navigators. A mixed methods approach was utilized for this purpose. The original STCW Table A-II/1 consisted of 66 items distributed within 19 competence themes. After performing EFA on the 109 collected responses, only 41 KUPs were found relevant for future autonomous operations distributed within 11 competences themes. These themes were identified as - (1) Position fixing and watchkeeping (2) Inspect and report defects to cargo spaces, hatch covers, and ballast tanks (3) Prevent, control and fight fires onboard (4) Contribute to safety of personnel and ships (5) Use of RADAR, ARPA, and ECDIS to maintain safety of navigation (6) Application of leadership and teamworking skills (7) Ensure compliance with pollution prevention (8) Damage control and distress communication (9) Application of meteorological information in navigation (10) Reporting and communication (11) Manoeuvring and maintaining seaworthiness of ship. These are the themes related to technical skills relevant for future autonomous operations for navigators. The individual KUP items which were rated as most important for future autonomous operations were – (1) Ability to take precautions for the protection of passengers in emergency situations (KUP-26) and (2) Ability to take initial actions following a collision or a grounding (KUP-27). Additionally, A component of the questionnaire was dedicated to examining the new technical skill requirements not included in the present competency framework. As a result of thematic analysis, five main novel technical competency themes emerged - IT skills, safety and security management skills, knowledge of engine room operations, electronic equipment, and system integration.

In relation to the non-technical skills, initially a division was done as per the reviewed literature, and they were divided into – cognitive skills and social skills. Out of the five cognitive skills presented to the respondents, they rated the ability to maintain situational awareness as the most important cognitive skills. Further, through thematic analysis of their qualitative responses, five novel cognitive skills that could be relevant for future autonomous operations emerged, such as - non-routine problem solving, self-regulation capacity, critical thinking, mental readiness, and systemic thinking. Similarly, they were also asked to evaluate and comment on social skills. Out of the six available options, the respondents rated the ability to take leadership initiatives as the most important social skills. Through the thematic analysis of their responses, three additional social skills that could be relevant emerged as - the ability to develop trust in teams, the ability to adjust to cultural differences, and negotiation abilities.

The paper concluded by stating that the while development related to autonomous ship technologies are gathering pace in recent years, relatively less studies have been conducted which are related to competence modelling for the future seafarers who will be involved in these operations. The guidelines and standards through instruments like the STCW regulations will be needed in the future which could aid the MET community in preparing the future maritime workforce.

4.2 Summary and key findings from paper-2

The aim of paper-2 was to explore the level of technology self-efficacy and the level of technology use by the MET instructors. The Technology Proficiency Self-Assessment for the Twenty-First Century (TPSA-C21) questionnaire was used in this study to assess the self-reported technology proficiency of maritime instructors from a variety of MET institutes in Europe and the UK. The TPSA-C21 questionnaire contains 34 items that assess technology self-proficiency across six dimensions: (1) Email (2) World Wide Web (3) Emerging Tools (4) Technology with technology (5) Integrated Applications (6) Technology with emerging technology. Additionally, the level of use of technology in classroom was determined by the Concern Based Adoption Model (CBAM-LoU) which defines eight level of educational innovation: (1) Non-use (2) Orientation (3) Preparation (4) Mechanical use (5) Routine (6) Refinement (7) Integration (8) Renewal.

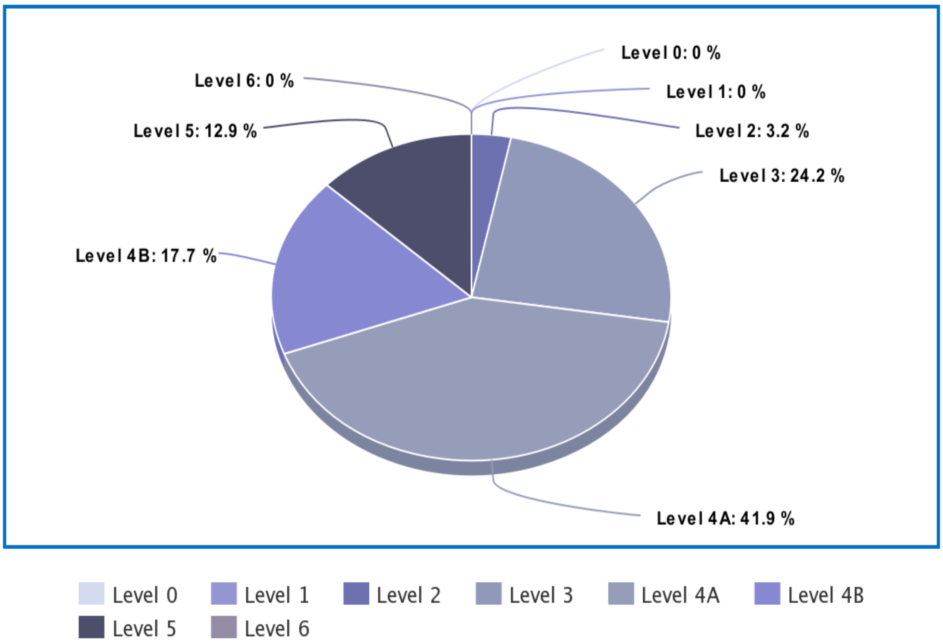

Figure 9 . Frequency distribution pie-graph for Level of Use (LoU) of technology in MET classrooms

The descriptive statistical analysis of obtained 62 responses indicated that on an average the respondents rated their technical proficiency on each of the items greater than 4.0, in a Likert scale varying from 1-5. However, that was not the case for Q. 8, 22 and 23, where the obtained average scores were – 3.37, 3.47 and 3.47 respectively. These results indicated a relative reluctance to utilize collaborative content creation, dissemination and the use of web 2.0 tools. This indicates that the MET instructors use the generic technology tools nominally, but not so much for constructivist purposes in the classroom. Further, in the CBAM-LoU scale as shown in the Figure 9, the percentage frequency distribution was highest for Level 4A, Routine (41.9%), which is described as being able to comfortably use information technology for teaching but not being able to make further impact through its use. This was followed by Level 3, Mechanical use (24.2%) of information technology. Evidently, none of the respondents selected Level 4B, 5 and 6, which correspond to refinement, integration and renewal levels of use.

The study concluded with stating that there is a scope for improvement for the MET instructors for teaching with a constructivist approach and the use of emerging technology. Further, through this study attention was drawn towards relatively less targeted area of the capacity development of MET instructors who have a crucial role in training the maritime workforce.

4.3 Summary and key findings from paper-3

In this paper, an AI chatbot was developed and implemented in the maritime classroom for assisting students in increasing their understanding regarding the International Regulations for Preventing Collisions at Sea or COLREGs. A total of 18 students enrolled in their Bachelors in Nautical Science program took part in this study. The theme of the paper-3 is related to the paper-2, as it builds on the findings and conclusions of the latter, where the role of MET instructors was described and elaborated upon. As noted earlier, one of the findings from paper-2 stated that the MET instructors require a more constructivist orientation in the classroom. Furthermore, their use of new emerging technology was also argued as an area requiring further investigation. These findings were considered in conjugation with a technology such as AI, which can support and be used for devising a digital distributed learning solution. Therefore, in the paper-3, the use of AI was explored through design and validation of the Chatbot for teaching and discussing COLREGs with the maritime trainees. The students practiced a subset of the COLREGs and evaluated the user interface of chatbot through the System Usability Scale (SUS). Some demographic questions such as student's prior experience with maritime navigation or interacting with a chatbot were also posed to understand the responses further. For the design of the chatbot, IBM Watson Assistant© service was utilized which enables the use of Application Programming Interfaces (APIs) on its cloud server. The chatbot was programmed to recognize and respond to queries regarding a subset of COLREGs (Rules 11-18) along with some generic responses. The chatbot was titled "FLOKI" and was conceptualized to act as the More Knowledgeable Other (MKO) in this instance that could respond to queries from the students. An evident advantage of using this approach was the possibility of the chatbot FLOKI to simultaneously engage multiple students repeatedly. The chatbot recognized the pre-defined contexts and responded with stored dialogue blocks.

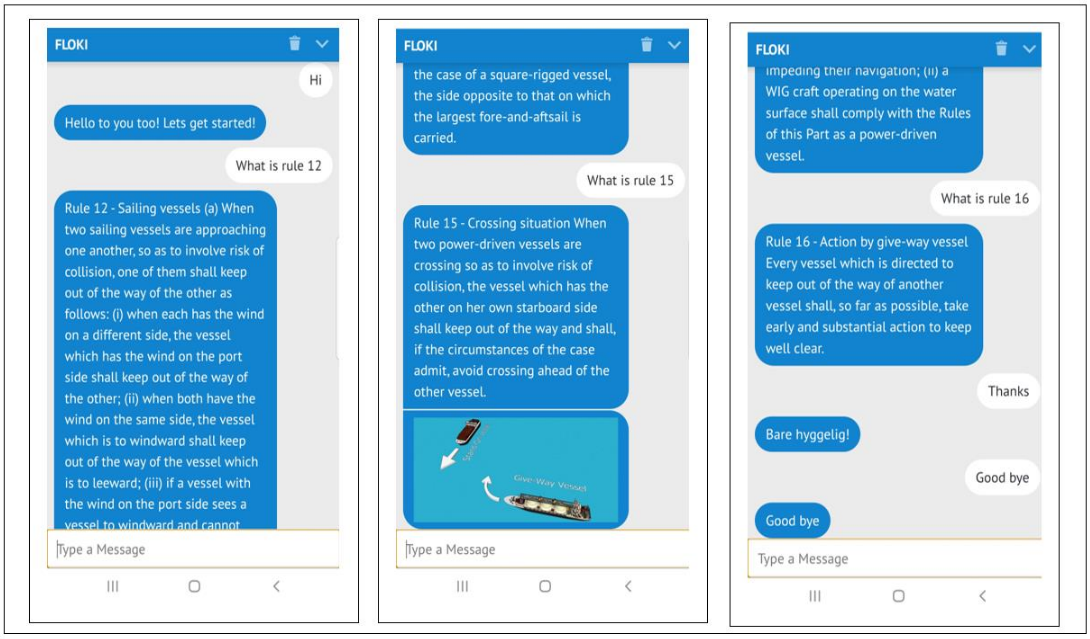

Figure 10. Example interaction of a student with AI chatbot FLOKI (Sharma et al., 2022)

An example of AI chatbot and student interaction is provided in the Figure 10 above. The overall score received by the chatbot was 73.72 in the SUS scale. It should be noted that this score does not correspond to a percentage. The median 50th percentile score for the SUS scale is 70.5 (Bangor et al., 2008). Therefore, the obtained score was above average and in the 3rd quartile of the total mean scores of the SUS scale. Non-parametric analysis were conducted to examine if there are any differences in the responses obtained through the SUS due to demographic grouping. A total of 10 respondents had stated that they have some experience with navigation and 8 had replied negatively for the same. The mean scores in SUS for these two groups were 74.97 and 72.70 respectively. The Mann-Whitney U test showed no significant difference in both groups at 0.05 significance level (U value = 38, Z score = 0.133, two tailed) with p=0.896. Similarly, the respondents were asked whether they had any experience in use of a chatbot prior to this exercise. A total of 11 respondents responded positively against 7 who responded negatively. The mean SUS scores of these two groups were 78.61 and 66.65 respectively. The Mann-Whitney U test showed no significant difference in both groups at 0.05 significance level (U value = 21, Z score = 0.153, two tailed) with p=0.123.

In conclusion, the AI chatbot received a positive evaluation in terms of its efficiency, effectiveness and satisfaction by the maritime students. The study present a proof-of-concept in terms of application of AI, more specifically, Natural Language Processing (NLP) for maritime education and training. It focused on the micro-context of learning interactions occurring between instructors and students mediated with technology. The recommendations from the paper were towards exploration of more application of digital technologies that can support classroom learning activities by promoting efficiency and leveraging the use of AI for the benefit of MET instructors and the students.

4.4 Summary and key findings from paper-4

The aim of paper-4 was to bring the focus on the current level of digital skills of the maritime trainees, which is often recognized as one of the indispensable 21st century skills necessary for the future workforce to succeed in post digital environments. A questionnaire known as Youth Digital Skills Indicator (yDSI) was administered to a total of 234 maritime trainees from the Philippines. The yDSI questionnaire evaluates the digital skills in four dimensions: (1) technical and operational skills (2) information navigation and processing skills (3) communication and interaction skills (4) content creation and production skills. The data was analysed using descriptive statistics and CFA.

The findings through comparison of percentage frequency distribution of each dimensions indicate that the maritime trainees rate their (1) technical and operational skills, and (3) communication and interaction skills higher than (2) information navigation and processing, and (4) content creation and production skills. The theoretical structure of the yDSI questionnaire was also evaluated through the CFA, which was found to be a satisfactory fit, with the following fit indices as shown in Table 2.

Table 2. CFA fit indices

Indices	**Value**
$\chi 2$	597.75
df	246
Sig.	0.000
RMSEA	0.078
RMR	0.063
CFI	0.895
TLI	0.882

Note - $\chi 2$ = Chi square, df = degrees of freedom, Sig = significance level, RMSEA = root mean square error of approximation, RMR = root mean squared residual, CFI = comparative fit index and TLI = Tucker-Lewis index (Sharma, 2022)

The paper identified a potential arena for improvement of digital skills of the maritime trainees with respect to two dimensions. The results indicated that the maritime trainees are not completely confident regarding interacting with information sources in digital environments and evaluating their credibility. Furthermore, they are relatively less proficient in content creation with respect to their learning. These issues could potentially impact the use of novel digital technologies in the classroom as the students will not be able to capitalize fully with the available digital affordances. The study re-iterates the importance of digital skills in professional vocational education and training environments.

5 Discussions

5.1 General discussions

This chapter discusses the obtained results in the thesis with the larger body of existing research literature and provides reflections regarding the implications of the findings. It also discusses the theoretical and methodological limitations of the current research. The four papers constituting the thesis provided empirical evidence related to the primary objective: the investigation of competence requirements for the future maritime workforce and barriers and opportunities regarding technology integration in maritime classrooms. As elaborated in the previous section, several key takeaways originate from each of the papers.

Paper-1 and paper-4, as noted earlier, focused on the macro-context regarding the use of technology in MET and competence development. With regards to novel competence requirements, paper-1 listed 11 competence themes that could be relevant for future maritime operations through a conceptual example of autonomous shipping: (1) Position fixing and watchkeeping (2) Inspect and report defects to cargo spaces, hatch covers, and ballast tanks (3) Prevent, control and fight fires onboard (4) Contribute to safety of personnel and ships (5) Use of RADAR, ARPA, and ECDIS to maintain safety of navigation (6) Application of leadership and teamworking skills (7) Ensure compliance with pollution prevention (8) Damage control and distress communication (9) Application of meteorological information in navigation (10) Reporting and communication (11) Manoeuvring and maintaining seaworthiness of ship (Sharma & Kim, 2021). These competences were listed for seafarers engaged in Degree 2 MASS operations who will be onboard such autonomous vessels. Similar findings are emerging from recent research literature related to competence requirements for operating autonomous ships in other projects parallelly. For example, in the EU project AUTOSHIP, Lee et al. (2022) describe the training framework for crew operating autonomous ships. They describe the use case scenario of Short Sea Shipping (SSS) autonomous vessels, which they explain corresponds to the Degree 2 MASS as per IMO. For the proposed use case, they have listed the following ten recommended skills for Remote Control Centre (RCC) Operators to manage the autonomous ships effectively: (1) Navigation (2) Deck operation (3) Cargo operation, Stability, and Ship Integrity (4) Machinery operation (5) Safety and Security (6) Environment Protection (7) Maintenance (8) Information technology (9) Ship administration and (10) Emergency Response. Although these skills are defined for RCC operators, the RCC does not necessarily corresponds to shore control, as it can also be a manned ship leading the convoy of other autonomous vessels. Furthermore, Lee et al. (2022, p.41) define some "general" competencies necessary for RCC operators. These competencies and skills, as defined by them, appear to be indicating towards a set of non-technical competencies/skills, although they have not explicitly stated so. They list eight such general competencies – (1) Knowledge of conventional ships (2) Good sense of situational awareness and digitalised information (3) Decisiveness & Quick-thinking skills (4) Mentality (5) Leadership, Teamwork skills and Social ability (6) Critical thinking, mental arithmetic calculations & Creative skills (7) Positive Attitude (8) Ability to remain calm and balanced. These competencies/skills seem to have good overlap with some of the "cognitive" and "social" skills as mentioned in the paper-1. Thus, it can be stated that overall, the skills listed by Lee et al. (2022) as relevant for Degree 2 MASS operations, show reasonable overlap with the findings from paper-1 of the thesis, although some minor areas of divergence also exist. Similarly, few commonalities in the findings of paper-1 were also observed with the research of Yoshida et al. (2020), where they examined the suitability of the STCW Table A-II/1 for the RCC operators using framework of situational awareness and goal-based gap analysis. Out of the existing competence themes, they propose strengthening and increasing the importance of about 11 themes, such as – Bridge Resource Management, Application of leadership and teamwork skills, Terrestrial and Coastal navigation, Electronic systems of position fixing and navigation, Watchkeeping, Radar navigation, Navigation using ECDIS, Navigation competence, Knowledge of regulatory framework, Theoretical and Fundamental Knowledge, and Practical ability related to navigation equipment (Yoshida et al., 2020, p.22). Upon closer inspection, there is a certain redundancy in their defined themes, and it is possible that the unique themes under the STCW Table-II/1, which should be retained, could have been further synthesized to about 9 themes. However, they also mention some additional competence themes that would be required for the RCC operators, such as - Experience of seagoing service, Fail-safe to the intermittence of data communication and Basic knowledge of wireless communication and data transfer. The latter two additional skills as mentioned, are similar to the findings of paper-1 where some of the additional technical skills required for future maritime workforce were mentioned as “IT skills” and “electronic equipment”. These findings also lend some evidence to the description of broader digital skills as necessary in the coming years. Yoshida et al. (2020) explicitly mentioned that “Celestial navigation” as a competence theme might be redundant in the future. This was also the finding in paper-1, as this competence theme, although traditionally rated as important part of navigator’s training, was not rated sufficiently relevant for the future by the respondents (Sharma & Kim, 2021). It could be relevant for the MET stakeholders to further investigate the suitability of competence themes, not only with respect to navigation officers, but also for other ranks and departments. If there are consistent evidence regarding redundancy of certain competence requirements, corresponding changes should be considered for revision in the STCW. With regards to individual Knowledge, Understanding and Proficiency (KUP) items, KUP 26 and 27 were rated as the most important in the era of autonomous maritime operations by the respondents. These KUPs broadly correspond to the ability to take appropriate action in emergency situations by the navigators. As more functions will be allocated to automation agents, the primary role of human operators will transition to responder of non-routine events. However, these developments will also entail corresponding risk of incorrect actions taken by human operators due to inherent limits with respect to how humans process information and respond. This is not entirely surprising as several literature sources have described humans as having poor monitoring capabilities and their tendency to be “out-of-the-loop” once they are in a supervisory capacity for autonomous agents (Endsley & Kiris, 1995; Porathe, 2021). As such, increasing emphasis on non-technical skills is expected to continue in the era of autonomous shipping. Emad et al. (2022) in their systematic literature review regarding the seafarer training needs for operating future autonomous ships had a similar outlook. They stated that while at the moment a robust framework and training curricula is lacking with regards to training seafarers for future maritime operations, it would likely include three dominant dimensions, such as – cognitive, communicative and operational skills. They reached this conclusion by reviewing the developments from other safety critical domains such as aviation, nuclear, road and railways, where the adaptation of automation related training frameworks traditionally preceded the maritime industry by few years. These findings do indicate a growing importance of non-technical dimensions of seafarer competence in the increasing automated shipping environments which should be considered by MET stakeholders.

The main findings from paper-4 were regarding the level of digital skills of maritime trainees as measured by the yDSI questionnaire. Considering the generic 21st century skills requirement, paper-4 targeted an essential component of the future skillset that is argued to be critical for all vocational workforce in the coming years. It was observed that the level of digital skills along the dimensions of information navigation and content creation was relatively lower for the students compared to other dimensions of digital skills. It suggests that participating students in the study were unclear on how to acquire relevant information and assess its authenticity while interacting with digital media. Furthermore, relatively low content creation and production ratings show that students need clarification on creating digital content that can be incorporated into their education and related copyright issues. The findings suggest that, in order to enable higher-order conversations in classroom instruction and curriculum design, a relatively low score on the dimensions mentioned above may pose a bottleneck for orienting students to create and assess knowledge (Krathwohl, 2002). It may have ramifications for introducing and modifying digital media in maritime classrooms. Without considering maritime students' basic digital literacy, any proposed instructional delivery options or educational innovation efforts will have a limited impact.

These findings indicate a scope of improvement, where the maritime students could improve on utilizing their digital skills for creating new knowledge with their peers as well as evaluating the accuracy and relevancy of digital content they are interacting with. While there are no studies to the best of my knowledge that have focus on digital skills and their impact on education of maritime students, some studies have discussed the digital environment where the future seafarers will operate and the need for corresponding skillsets. For example, Shahbakhsh et al. (2022) in their literature review, identified the key trends in maritime industry with respect to the ongoing digitalization and stated that the next generation of maritime industry will require considerable mediation of human and technological agents through digital interfaces. The need for adequate digital skills as a foundational knowledge for the seafarers would be a legitimate need in such a scenario. Similar views were voiced by Alop (2019) where he stated that the proficiency in ICT skills along with traditional seafaring knowledge will be key in preparing for intelligent shipping environment. However, all the above articles are conceptual in their nature and a more grounded approach to identify the role of digital skills for prospective maritime trainees is yet to emerge from the MET stakeholders. Despite this, the requirements for proficiency in digital skills for maritime students should also be viewed as a part of the larger vocational education and training related requirements in Industry 4.0. For instance, the International Labour Organization (ILO), in their roadmap for the digitalization of national Technical Vocational Education and Training (TVET) systems, stressed on the importance of digital literacy for lifelong learning for the workforce. (ILO, 2021). Similarly, the EU have defined a digital competence framework for its citizens (DigComp), considering the digital transformation occurring in the recent years and the significant need for ICT specialists in the coming future. Under this framework, EU have identified dimensions such as - information and data literacy, communication and collaboration, digital content creation, safety, and problem solving. Proficiency in these dimensions of the digital skills are envisioned by the EU in its overall educational policy (Vuorikari et al., 2022). It is also worth noting that not only the digital skills are necessary for the vocational employees from developed nations, but these skills could also provide a more level playing opportunity to the vocational employees from the developing nations through increased inclusivity and participation in global markets (Chetty et al., 2018). Thus, the need to cultivate digital skills for maritime trainees is aligned with the wider efforts towards sustainable development and should be considered at a global level. The paper-1 and paper-4 therefore, contributed towards understanding of the macro-context related to the technology use and competence development for the MET.

Undoubtedly, the role of MET instructors is also a key factor in understanding the potential use of technology and exploring various ways it can be utilized to deliver on the goals of educational programs. From the findings of paper-2, the level of use of technology in maritime classrooms and the self-reported technology proficiency of MET instructors were identified. The results from paper-2 through the use of TPSA-C21 indicated that the instructors reported less proficiency in the use of web 2.0 tools (e.g., social media/wiki/blogs). Further, their self-reported level of technology use in the classrooms hovered around "routine" applications predominantly (Level 4A), with none of the respondents reporting levels of use such as – refinement, integration, and renewal. As noted earlier, these findings indicate that although the MET instructors felt adequately competent in their use of majority of available technological affordances, there is still scope of improvement regarding use of emerging tools and their own pedagogical style. The findings draw the attention of the MET community towards relatively less addressed area regarding the need for professional development of the instructors, corresponding to the ongoing changes in the wider maritime domain. It is important to bring the level of technology proficiency of the MET instructors to the forefront because this self-reported gap in utilization of technology for education and training purposes can widen in the coming years. For example, with the rise in distributed learning modes enabled by advances in ICT, novel opportunities for creating digital content related to maritime subjects and their appropriate use will primarily rest with the MET instructors only. Failure to capitalize on such affordances will signify possibility of under-utilization of the technology infrastructure and its incomplete integration. As noted by Ertmer (2005), most of the innovations in the instructional practice are led by the instructors themselves and the attitude of the instructors towards the use of technology can be forming the "final frontier" which influences the end results regarding their integration. It is important to consider the professional development of the instructors for formulating policies and approach that takes into account the dynamic and technology powered learning experiences required for 21^{st} century education (Krishna, 2010). A natural question does arises with respect to how to support the professional development of the MET instructors. On the regulatory aspect, a possible step to adequately address these factors could be more explicit description of teaching methods, training aids and technology integration strategies to be employed in the digital learning environments by the MET instructors in IMO model courses 3.12 and 6.09. As described earlier, the IMO model courses 3.12 and 6.09 concern the training and assessment methods as well as organization of instructions for the MET instructors. A regulatory update and revision of their content and requirements could aid in laying the groundwork of changes. However, on the more pragmatic side, it would be about the organizational strategy of the MET institutes which could ensure more operational response. There are certain strategies that can be adapted to ensure the professional development of the instructors with respect to adequate utilization and integration of the technology. For instance, Potter and Rockinson-Szapkiw (2012), using a socio-constructivist approach, have described a model for effective professional development opportunities for the instructors. They describe three aspects of the model as (1) technology operation (2) technology application and (3) technology integration with mentor and community support. As per their model, initially, the instructors would need a basic understanding and familiarity with the use of any technology. Albeit familiarity with any technology is often only the basic step. Further, the instructors would need to explore the application of the technology in question, through relevant pedagogical exercises. It is important to use a hands-on approach with possible face to face sessions during this step. However, long-lasting positive changes in professional capacity can happen with a collaborative and community-oriented approach involving all the instructors in the organization, where they share their experiences and practices with the use of technology tools. Potter and Rockinson-Szapkiw (2012, p.24) advocate for the use of mentoring in this step. Observation of the new practices is more likely to be the most effective method for the instructors to transfer knowledge among each other. However, the final step would require active administrative support and intervention with respect to resources and planning. Similarly, Ertmer (2005) also elaborated upon the need for professional development of the instructors to better support technology integration in the classrooms. She stated that there is strong link between instructors existing beliefs and instructional practices. According to Ertmer (2005, p.32), there are three strategies through which a concrete shift in instructors' attitude towards technology can happen – (1) Personal experiences: relatively simple and lower-level use of technology can be used for initiation process (2) Vicarious experiences: observing peers using technology can help generate similar behaviour by the instructors. The instructor can contrast or draw parallel regarding their own approach by comparing with their peers. (3) Socio-cultural influences: the experiences of the instructors can be shaped by their participation in a defined professional community or through adapting what is considered to be a good instructional practice regarding technology use in their organization. For evaluating the effectiveness of professional development of MET instructors, an approach emerging from paper-2 can be adopted. Standard instruments such as TPSA-C21 or TPACK can be used to determine the level of technology self-efficacy before or after organizational intervention. It can also be used to compare differences in different geographical regions.

The results obtained from paper-2 influenced the objectives of paper-3. As the results suggested that there is a lack of utilization of emerging technologies by the MET instructors, a proof-of-concept of a digital tool powered by AI was conceptualized. The focus of paper-3 was towards design and evaluation of the AI Chatbot for a use case in maritime classroom. This resulted in the formation of the AI Chatbot "FLOKI", and subsequently it was evaluated for its perceived usability by the maritime trainees using the System Usability Scale (SUS). The overall usability findings of the chatbot in paper-3 show that it was well received by students in terms of efficacy, efficiency, and satisfaction. FLOKI exceeded the conventional standard in usability studies (73.7), as it scored higher than the median score of SUS scale (70.5). The non-parametric Mann-Whitney U test findings revealed no statistically significant differences in the chatbot's usability evaluation by students with prior navigation and COLREGs experience. The difference in average SUS scores between students who had prior experience dealing with a chatbot and those who did not had such experience was also not significant. However, an important purpose for the design of chatbot was towards demonstrating how emerging tools can be utilized in maritime classrooms. As the domain of AI expands to include improved models and interfaces to interact with, it simultaneously provides new opportunities for their application in education. Some of the potential benefits of AI in education, as noted earlier, were - the possibility to deliver personalized content on demand, the transfer of the repetitive aspects of the teaching tasks to intelligent agents and improving the overall quality and utilization concerning resources. However, these benefits can only be realized if AI solutions are properly implemented in respective educational contexts and tailored to meet the institutional needs. Owoc et al. (2021, p.10) have provided a general strategy for implementing AI in educational institutions. According to their guidelines, institutes can adopt a five-step process for integrating AI systems – (1) Plan and analyse: understanding the synergy between desired institutional goals and proposed solutions along with an estimation of resources (2) Design and specify: Narrow down to the functional requirements that the system should support (3) Implement and configure: The system should be commissioned and installed in the institutional software architecture (4) Test and evaluate: check for possible bugs, usability issues and performance (5) Monitor and support: providing support to the users and ensuring data storage integrity. These guidelines can be used and tailored according to the end goals and resources available. For example, in paper-3, the use case was related to the training of COLREGs for the B.Sc. in nautical science students. The proposed proof-of-concept provided a distributed learning solution in this regard. More diverse uses of AI in MET can be developed to address different aspects of educational programs. It can range from automated assessments to clustering of students according to their learning styles. The use of AI can therefore contribute towards supporting and, in some cases innovating the education and training processes.

The pedagogical use of the AI Chatbot was influenced by a socio-constructivist perspective towards learning. There were various reasons why this approach was adopted and should be considered to address some of the recognized challenges and opportunities evident in MET. Firstly, as explained earlier, the advances in ICT would present new modes of digital distributed learning. The MET community must leverage the ongoing digital advances to identify innovative use for supporting their educational programs. By their very nature, the digital distributed mode of learning will enhance connectivity and collaboration between the learners and the instructor. It will provide new modes of learning content delivery in addition to the existing ones. As a result, newer opportunities to collaborate and learn on virtual platforms will emerge (Miranda, 2007). To a certain extent, this is already possible and ongoing using the existing web 2.0 tools. However, the advances in ICTs would enable greater immersivity and the ability to transfer a variety of multimedia. In such instances, it is possible to enable the cultivation of digital community of learners. Therefore, the socio-constructivist learning perspective will be a more appropriate view of studying the learning process in such instances. As described earlier, it is a learner-centred theoretical lens that stresses the importance of the active construction of knowledge through interaction and scaffolding by more knowledgeable others. The interaction and scaffolding process, in turn, leads to the expansion of the Zone of Proximal Development (ZPD) that can enable the learner to articulate their knowledge further, compare it with their peers and internalize the new findings, building up on the past level of knowledge. In virtual learning environments, it is possible to trace the dynamic learning process by looking at the artefacts jointly developed by the learners and identify possible knowledge gaps. Furthermore, in technology-mediated social contexts, the learners could explore the co-construction of knowledge together, which will be actively supported by ICTs and supervised by the instructors. It could result in exposure to more diverse perspectives and greater student inclusion. The process of active engagement and collaboration can be useful for developing skills such as - critical thinking, self-regulation and communication, which along with digital skills, are part of the 21st century skills requirement that are argued to be necessary for vocational education and training for industry 4.0. The learning activities organized using this view in mind can support requirements related to both technical skills as well as non-technical skills. The MET community can benefit from further exploring use cases where such learning processes can be facilitated.

5.2 Theoretical and methodological limitations

As with most studies, the current thesis also consisted of certain theoretical and methodological limitations that should be considered while interpreting the findings emerging from this project. I would like to highlight them in this section.

In the arena of theoretical limitations, there are several examples which can be illustrated. For instance, the learning process was described using a selected educational theory out of a few dominant ones. However, a much larger variety of learning theories currently exist in educational research, and they have different antecedents and assumptions that could have also been considered. For example, theories such as Computer Supported Collaborative Learning (CSCL), or Computer Supported Cooperative Work (CSCW) are considered relevant when discussing modern vocational learning environments. They have emerged partly due to the unique nature of digital workspaces, though they trace some of their tenets to predecessor theories in learning sciences. However, these theories are just an example of the existing and ever-increasing learning theories currently employed in research. A comprehensive discussion and comparison of the educational theories would have been out of the scope of the intended research objectives for this project. Nevertheless, it is important to acknowledge that alternative viewpoints exist when considering the choice of educational theories. Similarly, the choice of survey instruments or the questionnaires also subjected the data collection to position towards specific theoretical stances. For example, the TPSA-C21 questionnaire by Christensen and Knezeck (2017) was adopted to assess the technology self-efficacy of the MET instructors. However, similar measures exist, which are also utilized for measuring the instructors' self-declared technology proficiency or knowledge levels. As described earlier, the TPACK framework given by Koehler and Mishra (2009) consists of three dimensions such as technology knowledge, pedagogical knowledge and content knowledge of the instructors. The questionnaire based on TPACK framework, such as the one developed by Schmidt et al. (2009), could also have been used in such instances. Specifically, the part of questionnaire having the technology dimension related questions would have provided another way of assessing the technology self-efficacy of the MET instructors. Moore-Hayes (2011) has also provided a 5 item scale for evaluating the technology self-efficacy of instructors. However, it was felt that it might not adequately capture the whole continuum of available technologies and their use in instruction. Therefore, TPSA-C21 was selected for the purposes of collecting the data. In the case of the evaluation of usability, the System Usability Scale (SUS) was utilized (Brooke, 1996). However, there are various options that closely resemble SUS in the outcomes such as Post Study System Usability Questionnaire (PSSUQ). PSSUQ scale is designed to measure the perceived satisfaction with computer-based systems or applications and utilizes 16 items to measure it along the dimensions of system, information and interface quality (Lewis et al., 1990). As such, it could have also been utilized. However, due to the choice of item wordings and relative simplicity in use, the selection subjectively tipped towards SUS for evaluating the perceived usability of AI Chatbot. In the end, only one approach could be used in the studies, however, it is important to acknowledge alternative questionnaires, as the choice of wording in each of them do impact the responses of the users. This is equally applicable for the use of yDSI questionnaire, where the intention was towards assessment of the digital skills of the students and several similar instruments are present. In summary, the selection of one of the instruments, available from a set of instruments with similar utility objective, correspondingly led to measurement of the factors associated with their underpinning theories.

Regarding the methodological limitations, as noted earlier, the choice of research paradigm, i.e., a post-positivist approach, imposed certain limitations throughout the project. Firstly, there was an evident issue of sample size in some of the studies, namely paper-2 and paper-3. Both of these studies could have benefited from a larger sample size than what was obtained. However, to cater to the limited sample size to a certain degree, only non-parametric tests were utilized when calculating inferential statistics in these two papers, thereby not requiring assumptions regarding the normal distribution of data. Nonetheless, larger sample sizes do reinforce the generalizability of the results. As such, the findings should only be considered relative to the obtained sample sizes, and caution should be exercised against over-interpretation. There are also various limitations due to the data collection steps involved in the thesis. For example, the majority of the collected empirical data was in the form of online surveys, except in paper-3. Such a form of data collection can be viewed as having a rigid and narrow structure of questions and being impersonal, as it does not offer the possibility of further interaction with the respondents. Additionally, online surveys do not capture nuanced qualities like behaviour, emotion and other form of non-verbal feedback from the respondents, which can be possible in a face-to-face method of collecting the data. Another inherent limitation concerning survey questionnaires is the possibility of structural bias. However, since most of the survey instruments were validated scales, an effort was taken to mitigate its possibility. Finally, there is a recognized issue known as "satisficing" in surveys, sometimes called "survey fatigue". Satisficing occurs due to time constraints of the respondents or lack of interest in accurately answering the survey questionnaire. It was mitigated to a certain degree by removing the "straight-lined" responses from the obtained data and calculating various reliability and validity parameters to ascertain if the factors are correctly and reliably loading as per their theoretical structure. The steps like confirmatory analyses and calculation of Cronbach's alpha, for example, helped address this issue to a certain extent. The obtained values of these parameters were mostly found satisfactory with the various thresholds defined in the research literature as described in the methodology section. As acknowledged earlier, a more qualitative approach could also have assisted in understanding the subtleties regarding the measurement of various factors. It would have been possible to go one level further in the investigation and pose follow-up queries with respect to each scale. This approach was adopted in paper-1 and was helpful in understanding the competence requirements more holistically. Due to resource constraints, it was not possible to repeat in in the subsequent papers. It should be acknowledged that a mixed method approach can certainly be preferable and satisfactory in terms of achieving the research objectives. However, there are certain limitations with respect to qualitative data collection and analysis as well when it was employed in paper-1. In relation to the obtained qualitative data, it is also worth describing the specific limitations. The thematic analysis process of the qualitative data was a subjective process and therefore it was a function of my own worldview and biases. The limitations of the survey method also apply to the qualitative data as it was not obtained through face-to-face interaction, rather, it was obtained through open-ended questions in the online survey questionnaire, which generated a collected set of texts. Despite being richer than the Likert scale responses, it was, therefore, still not possible to extract nuances from the obtained data. It should also be noted that the respondent pool was international. However, the questions that were asked were in the

English language. It is possible that some of the respondents did not correctly comprehend the original meaning or phrasing behind the questions due to the fact that English might not be their first language. As such, certain variances can be expected in meaning due to subjective interpretations by the respondents.

5.3 Revisiting the research objectives

The primary research objective of the thesis was to investigate the novel competence requirements relevant for the future maritime workforce, as well as the barriers and opportunities for integrating technology in the maritime educational settings. The results obtained from the thesis contributed to this thematic area for the MET domain. Taking into account the role of navigation officers at an operational level, the competence areas which will be potentially relevant were described. The findings indicate that the following 11 competence areas could be particularly important: (1) Position fixing and watchkeeping (2) Inspect and report defects to cargo spaces, hatch covers, and ballast tanks (3) Prevent, control and fight fires onboard (4) Contribute to safety of personnel and ships (5) Use of RADAR, ARPA, and ECDIS to maintain safety of navigation (6) Application of leadership and teamworking skills (7) Ensure compliance with pollution prevention (8) Damage control and distress communication (9) Application of meteorological information in navigation (10) Reporting and communication (11) Manoeuvring and maintaining seaworthiness of ship. Furthermore, five additional novel technical competence themes were described as - IT skills, safety and security management skills, knowledge of engine room operations, electronic equipment, and system integration. Regarding non-technical skills, the results indicated the ability to maintain situational awareness and leadership skills as particularly relevant for the future maritime operations. The novel non-technical skills that could also be relevant were listed as - non-routine problem solving, self-regulation capacity, critical thinking, mental readiness, systemic thinking, the ability to develop trust in teams, the ability to adjust to cultural differences, and negotiation abilities. With regards to the 21st century skills requirements for industry 4.0, an analysis with respect to digital skills of maritime trainees was carried out. Out of the four dimensions of the digital skills, the results indicated some scope of improvement with respect to content creation and information processing dimensions, in order to capitalize on modern technological affordances. The role of MET instructors, as described earlier, is vital for ensuring that the future maritime workforce possess the skillsets described above. Through the use of scales such as TPSA-C21 and CBAM-LoU, the thesis gathered evidence regarding the level of technology proficiency and integration of MET instructors. The findings indicated a relatively low level of proficiency in the use of web 2.0 tools compared to other forms of ICTs. Additionally, it was observed that the instructors utilized the technology pre-dominantly at "routine" or "mechanical" levels compared to higher levels such as refinement, integration or renewal that could have been explored. The use of emerging technologies such as AI and their possible role in innovating the education and training was discussed. An AI Chatbot utilizing the NLP capabilities was presented as a proof-of-concept for the application in MET. The process and functioning of the AI Chatbot for training COLREGs was described. The AI Chatbot received satisfactory usability score as observed through the use of SUS. Further opportunities with the use of similar digital distributed learning tools and by adapting a socio-constructivist perspective of learning to capitalize on advancing ICTs for were discussed. The thesis therefore elaborated upon both macro and micro contexts related to digitalization, competence development and use of technology in MET, along with highlighting the role of MET instructors and the need for their continuous professional development.

5.4 Future research directions

The results from the individual studies delineated knowledge of the trends related to competence development, technology integration, and digital skills of students and instructors in maritime classrooms. However, avenues of future research on these topics were also uncovered as a result. Some of the recommended areas of future research would be the investigation of the suitability of other stipulated and additional competence requirements for the marine engine officers (Table III/1) and other departments as outlined in the STCW. The knowledge regarding changing roles of other ranks and departments would be instrumental in understanding the regulatory changes required more holistically. Additionally, studies highlighting the generic 21st-century skills and their integration into the MET curriculum for future seafarers to prepare them for modern maritime work environments and beyond are also required. There is a need for systematic anticipation of future skills requirements for seafarers, not limited to merely obtaining certificates of competency. The findings from the thesis could aid in the competence modelling of existing and new roles within the maritime industry. Further research would also be needed with regard to the professional development of MET instructors. Future studies can be carried out concerning the technology self-efficacy of maritime instructors and its impact in the classroom utilizing a qualitative approach, for example. Such an approach could enable more insights regarding the perceived barriers experienced by the MET instructors. The data should be collected from geographical regions other than Europe and can be compared with the findings from the thesis. Finally, the involvement of emerging technologies such as AI in maritime classrooms will present a multifaceted opportunity for developing efficient approaches to prepare future seafarers. The MET stakeholders would need further exploration and understanding of the varied capabilities of the AI systems. Correspondingly, at an institutional level, there would be a need to investigate specific curriculum areas that could be functionally allocated to such systems. The use of new distributed modes of learning that enable the collective participation of learners and instructors requires an understanding of the pedagogical strategies that should be utilized to meet the goals of the educational program. It is another area that requires further research for the benefit of the MET stakeholders.

6 Conclusion

The dynamic nature of changes with advancements in digitalization and automation would require corresponding changes in maritime education and training. The present thesis aims to contribute actionable knowledge regarding several areas within the MET domain, which will require renewed focus in the face of upcoming changes in shipping at large. Topics such as competence requirements, technology integration and professional development of the MET instructors were investigated in the thesis. Adequately preparing the future workforce of a global evolving industry requires efforts on a greater scale. The scope of technology contributing towards competence development, capacity building, and safe maritime operations is vast. It will require a continuous evaluation of benefits, limitations and various perspectives from maritime stakeholders to address the maritime industry's digital transformation conundrum. A proactive approach from the MET community and adaptation of regulatory advances can facilitate the transition to the post-digital era.

6.1 Findings

- Considering the technological advances in maritime industry, certain new technical competencies would be required for seafarers as expressed by a section of MET stakeholders. In the case of navigators, engaged in operational capacity in semi-autonomous operations, eleven competence themes are described, from a subset of the existing Knowledge, Understanding and Proficiency (KUP) items in the STCW.
- With regards to non-technical skills, the ability to maintain adequate situational awareness and the ability to take leadership initiatives are rated as particularly important by the respondents. There is also emphasis on the emergency preparedness of the seafarers on the account of increasing automation and transition to more supervisory duties.
- The level of digital skills of maritime students as per the 21st century skills framework for industry 4.0 environments were evaluated. The maritime students from a major maritime workforce supplier nation rated their levels of digital skills along four dimensions. It was noticed that the students had relatively less proficiency in information processing and content creation aspects of digital skills. A confirmatory factor analysis also evaluated the performance of the scale and its theoretical structure.
- The level of technology proficiency and its integration is measured from a sample of MET instructors using a standardized scale. The MET instructors in Europe rated their usage of web 2.0 tools and emerging technology lower than other standard forms of ICTs. Furthermore, they reported their use of technology in maritime classrooms at “routine” or “mechanical” level in their teaching, against the expected levels of refinement, integration and renewal.

- The use of AI tools for their potential application for MET was investigated. The proof-of-concept designed for demonstrating a use case in COLREGs training received adequate usability score. No difference with respect to prior experience of navigation or knowledge of COLREGs was observed.

6.2 Recommendations

- Due to the changing operational environment as a result of industry 4.0, integration of 21st century skills in curriculum should be considered for adequately preparing maritime workforce and ensuring continuous employability.
- The competence requirements for management level officers and other ranks in shipping as per the STCW framework need to be determined and tailored to the evolving maritime operations. There is a need to further investigate the framework of non-technical skills in light of ongoing automation and digitalization in maritime domain.
- The MET community need to focus simultaneously on the professional development of MET instructors. This is vital for developing successful pedagogical strategies to prepare the future maritime workforce. With regards to technology integration in maritime classrooms, standard scales can be used to establish benchmarks and facilitation of comparisons. At local or institutional level, qualitative studies can also provide evidence regarding perceived barriers and opportunities.
- Advances in the capabilities of AI present multi-faceted opportunities in education. Further avenues where AI can be used to support MET and strategies for ensuring its optimal integration at MET institutes needs to be identified.
- Due to increase in digital distributed learning solutions, corresponding adaptation of pedagogical approach should be explored. Utilizing perspectives such as socio-constructivist theory and inculcating learning activities that involve co-construction of knowledge, peer assessment and similar strategies can be adapted in this regard to meet the educational goals.

7 References

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8 Appendices

A.1 Informed Consent form for Paper-1

University of South-Eastern Norway

Welcome to the research study!

The increased use of automation and digitalization in the maritime industry has gradually changed the operational environment of ships and the knowledge required for the seafarers. In this research, we would like to hear your expert opinions and viewpoints on the skills future seafarers need to excel in the era of autonomous shipping.

The study should take you around 10 minutes to complete. Your participation in this research is voluntary and your responses are anonymous with no personal information being collected during the survey. If you would like to contact the researchers in the study to discuss this research, please e-mail to: ams@usn.no.

The skill sets recognized from your responses will contribute to theory and practice, and encourage more thoughts and contributions for improving education and capacity building in the maritime industry.

Many thanks for your participation!

Amit Sharma, Tae-eun Kim
Doctoral Research Fellow
University Of South-Eastern Norway
Department of Maritime Operations

A.2 Informed Consent form for Paper-2

Informed Consent Form

Do you want to participate in the research project

"Application of Will, Skill, Tool, Pedagogy (WSTP) model for Maritime Education and Training" ?

This is a consent form for you to participate in a research project whose purpose is to determine which components of the Will, Skill, Tool, Pedagogy (WSTP) model affects the approach towards the level of technology integration for Maritime Education and Training instructors. In this note, we give you information about the objectives of the project and what participation will involve for you.

Purpose

The purpose of this research project is determine which component of the Will, Skill, Tool, Pedagogy (WSTP) model affects the approach towards the level of technology integration in the classroom by the maritime instructors. With your consent, a set of validated and standardized questionnaires will be offered to you to fill in either in paper or electronic format. The questionnaires aim to measure your technical proficiency, confidence and attitude towards the various technological tools used in teaching and your self-reported level of pedagogical competence. This research is part of a PhD project aimed to investigate the future competencies for maritime students and various pedagogical approaches that can be adapted by the maritime institutes to support them. The findings from this research project is aimed to be disseminated through a peer-reviewed manuscript for the stakeholders in the maritime community and also form a part of doctoral dissertation for the researcher.

Who is responsible for the research project?

The department of maritime operations at University of South-Eastern Norway and the principal investigator/PhD candidate is responsible for the project.

Why you are asked to participate?

You are being asked to participate in this study basis on your background as a Maritime Education and Training (MET) instructor. The respondents of this study are chosen through professional contacts with your parent organization through a non-random approach.

What does it mean for you to participate?

If you choose to participate in the project, it means that you fill out a questionnaire. It will take you about 45 minutes. The questionnaire contains questions about your technical proficiency, confidence and attitude towards the various technological tools used in teaching and your self-reported level of pedagogical competence. You can choose to fill the questionnaire in either paper based or electronic format. Your answers from the questionnaire will be collected and added with other respondents' answers to formulate an aggregate data set that will be analysed using a computer program. For the purpose of facilitating analysis, some background information such as Age, Gender, Nationality and Years of experience in your filed may be collected. However, this information will only be presented in an aggregate manner in the final analysis.

It is voluntary

It is voluntary to participate in the project. If you choose to participate, you can at any time withdraw this consent without giving any reason. All your personal data will be deleted. It will not have any negative consequences for you if you do not want to participate or later decide to withdraw.

Your privacy - how we maintain and use your information
We will only use your information for the purposes we have talked about in this letter. We treat the information confidentially and in accordance with policy. The information collected from you will only be available to the researcher stored securely in password protected devices. No directly identifiable information will be reflected in the analysis and only aggregate responses from group of respondents will be presented in the research manuscript.

What happens to your information when we finish the research project?
The information will be anonymized when the project ends / task is approved, which is scheduled is finish by 31st December 2021. The anonymous data will then be archived indefinitely in a password protected device.

Your rights
As long as you can be identified in the data, you are entitled to:

- Access the personal data which is stored about you, and to obtain a copy of the information
- Correct any personal information about you
- Delete the personal information about you and
- Send complaint to the Inspectorate for the processing of your personal data.

What gives us the right to process personal data about you?
We process information about you based on your consent. On request from University of South-Eastern Norway (USN), NSD - Norwegian Center for Research Data AS has concluded that the processing of personal data in this project is in compliance with privacy regulations.

Where can I find out more?
If you have questions about the study, or wish to exercise your rights, please contact:

- Amit Sharma, PhD research fellow, University of South-Eastern Norway
  ams@usn.no; +4745763384
- Paal Are Solberg, Data protection officer, University of South-Eastern Norway
  paal.a.solberg@usn.no; +4735575053
- Salman Nazir, Professor, University of South-Eastern Norway
  sna@usn.no; +4793438466

If you have questions related to NSD's assessment of the project, please contact:

• NSD - Norwegian Center for Research Data AS on email (personverntjenester@nsd.no) Or by phone: +4755582117.

With best regards

Amit Sharma
PhD research fellow
Department of maritime operations
University of South-Eastern Norway
ams@usn.no
+4745763394

Consent Statement

I have received and understood the information on the project “Application of the Will, Skill, Tool, Pedagogy (WSTP) for Maritime Education and Training” and have been given an opportunity to ask questions. I agree to:

- ☐ To participate in the survey questionnaire
- ☐ I agree that my data is processed until the project is completed

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(Signed by the project participant, date)

A.3 Informed Consent form for Paper-3

University of South-Eastern Norway

Informed Consent and demographics form

This is an information form aimed at sharing the objective of this study. Your background as a maritime trainee enrolled in Bachelor of nautical science program has made you eligible to act as a participant in this study. The study is aimed at evaluating different approaches to familiarize the knowledge of the International Regulations for Preventing Collisions at Sea (COLREGs) for the maritime trainees. No personal information will be collected, and the participation is entirely voluntary. The department of maritime operations and the Principal Investigator / PhD candidate is responsible for the project. The time duration for the participation would be about 30mins. Please feel free to ask any questions throughout the duration of the study to the Principal Investigator / PhD candidate.

☐ **I understand the above and agree for participation in the study**

Please answer the following demographic questions before commencing the study:

Gender: ☐ **Male** ☐ **Female**

On a scale of 1-7 (lowest to highest), how would you rate your familiarity with the International Regulations for Preventing Collisions at Sea (COLREGs)?

Not proficient	1	2	3	4	5	6	7	Very proficient

Do you possess experience of working with boats, with navigation related task for work or leisure?

☐ **Yes** ☐ **No**

On a scale of 1-7 (lowest to highest), how would you rate your use of personal digital tools or gadgets (e.g. Laptop, Smartphone, Tablets, etc.) ?

Dont use at all	1	2	3	4	5	6	7	Used extensively

Have you interacted with a Chatbot (Intelligent Conversational Agent) earlier in your day-to-day life?

☐ **Yes** ☐ **No** ☐ **Can't say**

A.4 Informed Consent form for Paper-4

University of South-Eastern Norway

Evaluation of Digital Skills for maritime students

This is an information form aimed at sharing the objective of this study. Your background as a maritime trainee enrolled in Bachelor of nautical science program has made you eligible to act as a participant in this study. The study is aimed at evaluating digital skills of the maritime trainees. No personal information will be collected, and the participation is entirely voluntary. The department of maritime operations and the Principal Investigator / PhD candidate is responsible for the project. The time duration for the participation would be about 15 mins. Please feel free to ask any questions throughout the duration of the study to the Principal Investigator / PhD candidate.

☐ **I understand the above and agree for participation in the study**

Please answer the following demographic questions before commencing survey:

Gender: ☐ **Male** ☐ **Female**

Age:

Country of residence:

Which Bachelors program are you part of :

- ☐ **B.sc. in nautical sciences**
- ☐ **B.sc. in marine engineering**
- ☐ **B.sc. in shipping and logistics**

The questionnaires below are validated and standard youth Digital Skills Indicator scale. They have been used by researchers in the past. We will use your responses to gather information regarding digital skills and their use. Please complete all items even if you feel that some are redundant. This should require about 15 minutes of your time. Usually it is best to respond with your first impression, without giving a question much thought. Your answers will remain confidential.

A.5 Description of contribution from other researchers

The PhD project was an undertaking for me as a principal investigator which required substantial support to be executed. There were many individuals who supported me directly and indirectly. However, it is important to acknowledge the contribution of some researchers who had significant intellectual inputs in the research papers of the thesis as well as the overall research project.

Prof. Salman Nazir: Prof. Salman Nazir acted as the main supervisor for the PhD project and provided guidance for the same. He contributed in brainstorming of research ideas as well as towards the formulating critical discussions. He had direct contributions in paper-2 of the thesis with respect to being a co-author as well as assisting in data collection for the study. He also acted as co-author in paper-3 of the thesis and assisted in write-up and presentation of the results.

Ass. Prof. Tae-eun Kim: Ass. Prof. Tae-eun Kim had significant contributions in paper-1 of the PhD thesis. Apart from acting as co-author for the same, she played a lead role in data collection. She had contributions in data analysis for Exploratory Factor Analysis and Thematic Analysis methods used in the paper as well as write-up and presentation of the results.

Mr. Per Eirik Undheim: Mr. Per Eirik Undheim had significant contributions in paper-3 of the PhD thesis. Apart from acting as co-author for the same, he played a lead role in planning of the experiment. He had contributions towards the pedagogical dimension of the paper and provided initial feedback towards the use of AI Chatbot. He also contributed to the write-up of the paper and presentation of the results.

A.6 Technology Proficiency Self-Assessment for 21st century (TPSA-C21) questionnaire by Christensen and Knezek (2017)

I feel confident that I could...

	SD	D	U	A	SA
1. ... send e-mail to a friend.	1	2	3	4	5
2. .. subscribe to a discussion list.	1	2	3	4	5
3. ... create a distribution list" to send e-mail to several people at once.	1	2	3	4	5
4. .. send a document as an attachment to an e-mail message.	1	2	3	4	5
5. .. keep copies of outgoing messages that I send to others.	1	2	3	4	5
6. ... use an Internet search engine (e.g., Google) to find Web pages related to my subject matter interests.	1	2	3	4	5
7. ... search for and find the Smithsonian Institution Web site.	1	2	3	4	5
8. ... create my own web page.	1	2	3	4	5
9. ... keep track of Web sites I have visited so that I can return to them later. (An example is using bookmarks.)	1	2	3	4	5
10. ... find primary sources of information on the Internet that I can use in my teaching.	1	2	3	4	5
11. ... use a spreadsheet to create a bar graph of the proportions of the different colors of M&Ms in a bag.	1	2	3	4	5
12. ... create a newsletter with graphics.	1	2	3	4	5
13. ... save documents in formats so that others can read them if they have different word processing programs (eg., saving Word, pdf, RTF, or text).	1	2	3	4	5
14. …use the computer to create a slideshow presentation.	1	2	3	4	5
15. ... create a database of information about important authors in a subject matter field.	1	2	3	4	5
16. …write an essay describing how I would use technology in my classroom.	1	2	3	4	5

17. ... create a lesson or unit that incorporates subject matter software as an integral part.	1	2	3	4	5
18. ... use technology to collaborate with teachers or students, who are distant from my classroom.	1	2	3	4	5
19. … describe 5 software programs or apps that I would use in my teaching.	1	2	3	4	5
20. ... write a plan with a budget to buy technology for my classroom.	1	2	3	4	5
21. …integrate mobile technologies into my curriculum.	1	2	3	4	5
22. …use social media tools for instruction in the classroom. (ex. Facebook, Twitter, etc.)	1	2	3	4	5
23. …create a wiki or blog to have my students collaborate.	1	2	3	4	5
24. …use online tools to teach my students from a distance.	1	2	3	4	5
25. …teach in a one-to-one environment in which the students have their own device.	1	2	3	4	5
26. …find a way to use a smartphone in my classroom for student responses.	1	2	3	4	5
27. … use mobile devices to connect to others for my professional development.	1	2	3	4	5
28. … use mobile devices to have my students access learning activities.	1	2	3	4	5
29. … download and listen to podcasts/audio books.	1	2	3	4	5
30. … download and read e-books.	1	2	3	4	5
31. … download and view streaming movies/video clips.	1	2	3	4	5
32. … send and receive text messages.	1	2	3	4	5
33. … transfer photos or other data via a smartphone.	1	2	3	4	5
34. … save and retrieve files in a cloud-based environment.	1	2	3	4	5

A.7 Concern Based Adoption Model Level of Use (CBAM-LoU)

Concerns- Based Adoption Model (CBAM) Levels of Use of an Innovation Please mark one category that best indicates your overall level of use of information technology.	
◯	**Level 0: Non-use** I have little or no knowledge of information technology in education, no involvement with it, and I am doing nothing toward becoming involved.
◯	**Level 1: Orientation** I am seeking or acquiring information about information technology in education.
◯	**Level 2: Preparation** I am preparing for the first use of information technology in education.
◯	**Level 3: Mechanical Use** I focus most effort on the short-term, day-to-day use of information technology with little time for reflection. My effort is primarily directed toward mastering tasks required to use the information technology.
◯	**Level 4 A: Routine** I feel comfortable using information technology in education. However, I am putting forth little effort and thought to improve information technology in education or its consequences.
◯	**Level 4 B: Refinement** I vary the use of information technology in education to increase the expected benefits within the classroom. I am working on using information technology to maximize the effects with my students.
◯	**Level 5: Integration** I am combining my own efforts with related activities of other teachers and colleagues to achieve impact in the classroom.
◯	**Level 6: Renewal** I reevaluate the quality of use of information technology in education, seek major modifications of, or alternatives to, present innovation to achieve increased impact, examine new developments in the field, and explore new goals for myself and my school district.

A.8 System Usability Scale (SUS) by Brooke (1996)

System Usability Scale (SUS)

	Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1. **I think I would like to use this tool frequently.**	☐	☐	☐	☐	☐
2. **I found the tool unnecessarily complex.**	☐	☐	☐	☐	☐
3. **I thought the tool was easy to use.**	☐	☐	☐	☐	☐
4. **I think that I would need the support of a technical person to be able to use this system.**	☐	☐	☐	☐	☐
5. **I found the various functions in this tool were well integrated.**	☐	☐	☐	☐	☐
6. **I thought there was too much inconsistency in this tool.**	☐	☐	☐	☐	☐
7. **I would imagine that most people would learn to use this tool very quickly.**	☐	☐	☐	☐	☐
8. **I found the tool very cumbersome to use.**	☐	☐	☐	☐	☐
9. **I felt very confident using the tool.**	☐	☐	☐	☐	☐
10. **I needed to learn a lot of things before I could get going with this tool.**	☐	☐	☐	☐	☐

A.9 Youth Digital Skills Indicator (yDSI) by Helsper et al. (2020)

Part -1

1.	I know how to adjust privacy setting	1	2	3	4	5	6	7
2.	I know how to turn off the location settings on my mobile device	1	2	3	4	5	6	7
3.	I know how to protect a mobile device (e.g. with a PIN, a screen pattern or a finger print)	1	2	3	4	5	6	7
4.	I know how to store photos, documents, contacts or other files in the cloud (e.g. Google Drive, iCloud)	1	2	3	4	5	6	7
5.	I know how to use private browsing (e.g. incognito mode)	1	2	3	4	5	6	7
6.	I know how to block unwanted pop-up messages or ads	1	2	3	4	5	6	7
7.	I know how to use programming language (e.g. XML, Python, Java, C++)	1	2	3	4	5	6	7

Part -2

1.	I know how to choose the best keywords for online search	1	2	3	4	5	6	7
2.	I know how to find a website I have visited before	1	2	3	4	5	6	7
3.	I know how to find information on a website no matter how it is designed	1	2	3	4	5	6	7
4.	I know how to use advanced search functions in search engine	1	2	3	4	5	6	7
5.	I know how to check if the information I find online is true	1	2	3	4	5	6	7
6.	I know how to figure out if a website can be trusted	1	2	3	4	5	6	7

Part -3

1.	Depending on who I want to communicate with, I know which medium or tool to use (make a call, send a WhatsApp message, send an email, etc.)	1	2	3	4	5	6	7
2.	I know when to mute myself or disable video in online interactions	1	2	3	4	5	6	7
3.	I know which images and information of me it is OK to share online	1	2	3	4	5	6	7
4.	I know when it is appropriate and when it is not appropriate to use emoticons(e.g. smileys, emojis) or text speak or capital letters	1	2	3	4	5	6	7
5.	I know how to report negative content relating to me or a group to which I belong	1	2	3	4	5	6	7
6.	I know how to recognise when someone is being bullied online	1	2	3	4	5	6	7

Part -4

1.	I know how to create something which incorporates different digital media (images, music, video, GIFs)	1	2	3	4	5	6	7
2.	I know how to edit existing online images, music and videos	1	2	3	4	5	6	7
3.	I know how to ensure that many people will see what I put online	1	2	3	4	5	6	7
4.	I know how to change the things I put online depending on how other people react to it	1	2	3	4	5	6	7
5.	I know how to distinguish sponsored and non-sponsored content	1	2	3	4	5	6	7
6.	I know when I am allowed to use content covered by copyright	1	2	3	4	5	6	7

A.10 Outline of the analysis for paper-1

- The sample was checked for sampling adequacy using Kaiser-Meyer-Olkin test. The Bartlett’s test of sphericity was also significant.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.754
Bartlett's Test of Sphericity	Approx. Chi-Square	2533.630
	df	780
	Sig.	.000

- Factor extraction method was Principal Component Analysis. Only the factors with eigenvalues greater than 1 were considered. 11 factors explained 72.6% of variance.

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings	
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance
1	10.519	26.298	26.298	10.51	26.298	26.298	3.539	8.848
2	3.923	9.808	36.106	3.923	9.808	36.106	3.330	8.324
3	2.560	6.400	42.506	2.560	6.400	42.506	3.125	7.812
4	2.072	5.180	47.686	2.072	5.180	47.686	3.024	7.560
5	1.860	4.649	52.335	1.860	4.649	52.335	2.901	7.253
6	1.627	4.067	56.402	1.627	4.067	56.402	2.891	7.228

7	1.573	3.932	60.334	1.573	3.932	60.334	2.662	6.655
8	1.317	3.293	63.627	1.317	3.293	63.627	2.234	5.585
9	1.291	3.228	66.855	1.291	3.228	66.855	1.975	4.939
10	1.219	3.047	69.901	1.219	3.047	69.901	1.786	4.466
11	1.078	2.694	72.596	1.078	2.694	72.596	1.570	3.925
12	.891	2.227	74.822					
13	.842	2.106	76.928					
14	.813	2.031	78.959					
15	.713	1.783	80.742					
16	.645	1.612	82.353					
17	.590	1.475	83.828					
18	.560	1.401	85.229					
19	.546	1.365	86.594					
20	.493	1.232	87.826					
21	.465	1.161	88.988					
22	.432	1.081	90.068					
23	.383	.957	91.025					
24	.375	.939	91.964					
25	.363	.907	92.870					
26	.333	.833	93.703					
27	.312	.780	94.483					
28	.282	.705	95.188					

29	.264	.660	95.847					
30	.257	.643	96.491					
31	.227	.568	97.059					
32	.200	.500	97.559					
33	.174	.435	97.994					
34	.163	.408	98.402					
35	.141	.351	98.753					
36	.126	.315	99.068					
37	.120	.301	99.369					
38	.106	.266	99.635					
39	.076	.191	99.826					
40	.070	.174	100.00					

- Factor 1 – Reliability and Descriptive statistics

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.829	.832	6

Item Statistics

	Mean	Std. Deviation	N
Q2_1	2.28	1.079	109
Q2_2	2.12	1.069	109
Q2_3	2.14	1.023	109
Q2_6	2.12	.910	109
Q2_7	2.44	1.190	109
Q2_15	2.02	.892	109

- Factor 2 – Reliability and Descriptive statistics

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.849	.851	5

Item Statistics

	Mean	Std. Deviation	N
Q2_38	2.42	.965	109
Q2_39	2.02	.805	109
Q2_40	2.17	1.035	109
Q2_41	2.27	1.060	109
Q2_42	2.08	.883	109

- Factor 3 – Reliability and Descriptive statistics

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.817	.816	4

Item Statistics

	Mean	Std. Deviation	N
Q2_51	1.96	1.045	109
Q2_52	1.96	1.009	109
Q2_53	1.71	.785	109
Q2_54	1.76	.827	109

- Factor 4 – Reliability and Descriptive statistics

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.817	.816	4

Item Statistics

	Mean	Std. Deviation	N
Q2_63	1.76	.827	109
Q2_64	1.70	.752	109
Q2_65	1.83	.887	109
Q2_66	1.85	.891	109

- Factor 5 – Reliability and Descriptive statistics

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.817	.816	4

Item Statistics

	Mean	Std. Deviation	N
Q2_22	2.06	.808	109
Q2_23	1.91	.764	109
Q2_24	1.73	.812	109
Q2_25	1.73	.777	109

- Factor 6 – Reliability and Descriptive statistics

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.817	.816	4

Item Statistics

	Mean	Std. Deviation	N
Q2_58	2.38	.941	109
Q2_60	2.43	.917	109
Q2_61	2.24	.971	109
Q2_62	2.10	.871	109

- Factor 7 – Reliability and Descriptive statistics

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.880	.880	3

Item Statistics

	Mean	Std. Deviation	N
Q2_44	1.72	.932	109
Q2_45	1.91	.928	109
Q2_46	1.85	.921	109

- Factor 8 – Reliability and Descriptive statistics

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.756	.765	3

Item Statistics

	Mean	Std. Deviation	N
Q2_27	1.51	.728	109
Q2_28	1.60	.783	109
Q2_29	1.97	.937	109

- Factor 9 – Reliability and Descriptive statistics

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.759	.762	3

Item Statistics

	Mean	Std. Deviation	N
Q2_9	2.48	.939	109
Q2_10	2.25	.983	109
Q2_11	2.41	.895	109

- Factor 10 – Reliability and Descriptive statistics

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.627	.630	2

Item Statistics

	Mean	Std. Deviation	N
Q2_31	2.23	1.033	109
Q2_17	2.22	.927	109

- Factor 11 – Reliability and Descriptive statistics

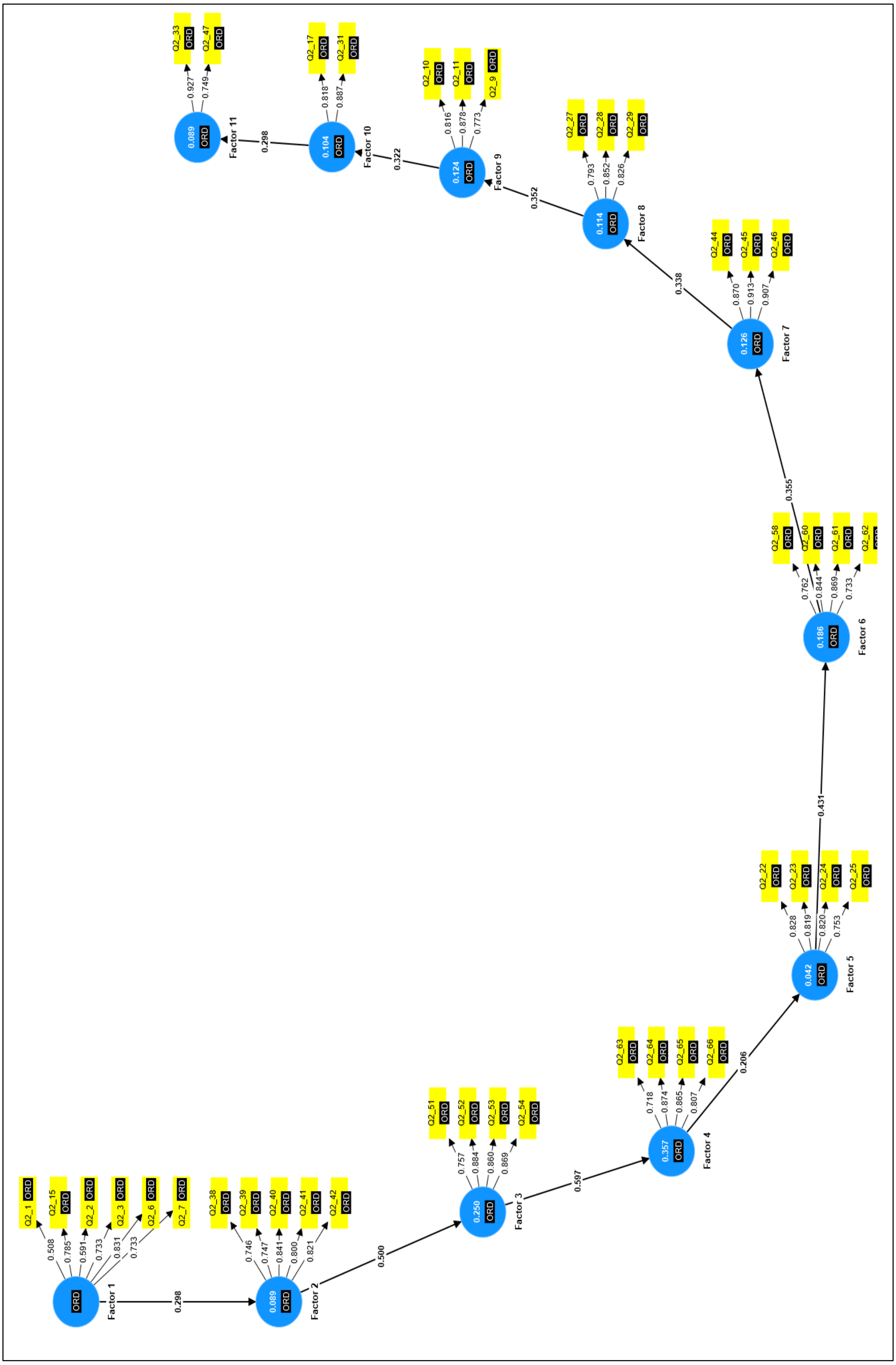
Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.615	.615	2

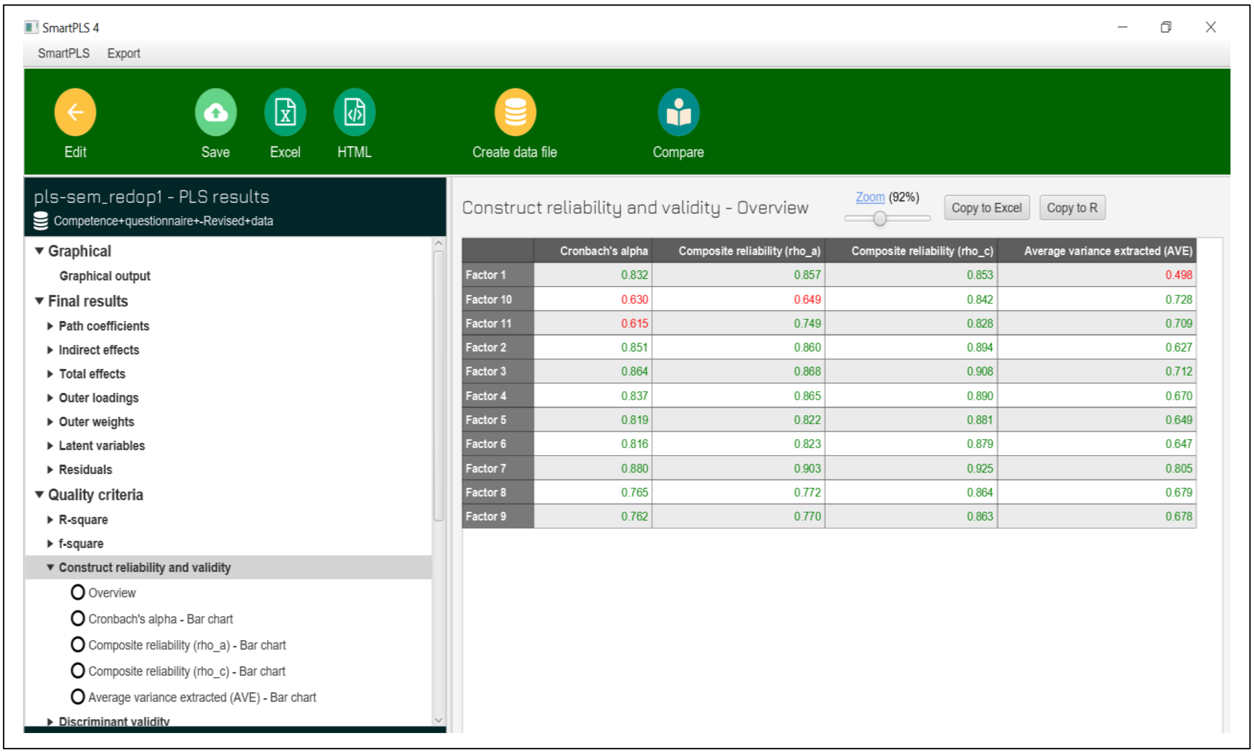
Item Statistics

	Mean	Std. Deviation	N
Q2_33	2.05	.917	109
Q2_47	2.13	.963	109

- **Confirmatory analysis illustration from SmartPLS4©**

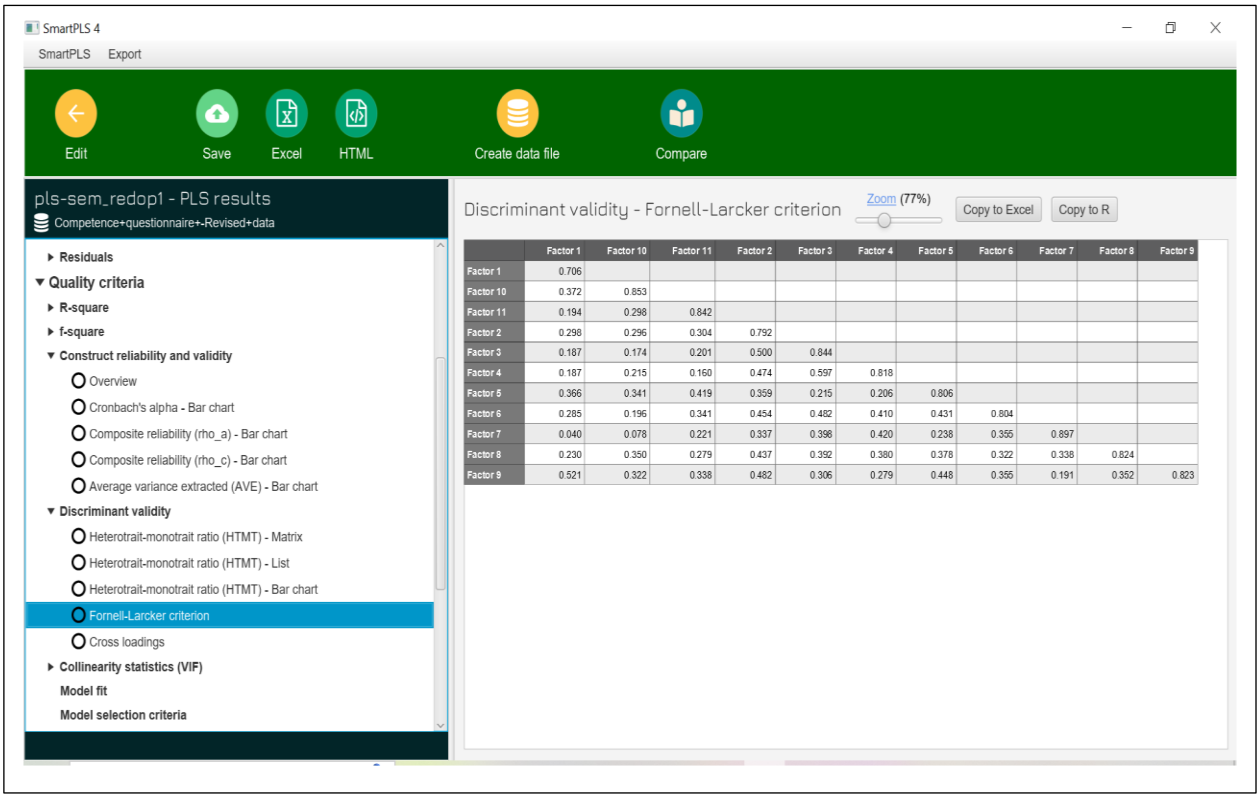


- **Reliability statistics from SmartPLS4©**



	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Factor 1	0.832	0.857	0.853	0.498
Factor 10	0.630	0.649	0.842	0.728
Factor 11	0.615	0.749	0.828	0.709
Factor 2	0.851	0.860	0.894	0.627
Factor 3	0.864	0.868	0.908	0.712
Factor 4	0.837	0.865	0.890	0.670
Factor 5	0.819	0.822	0.881	0.649
Factor 6	0.816	0.823	0.879	0.647
Factor 7	0.880	0.903	0.925	0.805
Factor 8	0.765	0.772	0.864	0.679
Factor 9	0.762	0.770	0.863	0.678

- **Validity statistics from SmartPLS4©**



	Factor 1	Factor 10	Factor 11	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9
Factor 1	0.706										
Factor 10	0.372	0.853									
Factor 11	0.194	0.298	0.842								
Factor 2	0.298	0.296	0.304	0.792							
Factor 3	0.187	0.174	0.201	0.500	0.844						
Factor 4	0.187	0.215	0.160	0.474	0.597	0.818					
Factor 5	0.366	0.341	0.419	0.359	0.215	0.206	0.806				
Factor 6	0.285	0.196	0.341	0.454	0.482	0.410	0.431	0.804			
Factor 7	0.040	0.078	0.221	0.337	0.398	0.420	0.238	0.355	0.897		
Factor 8	0.230	0.350	0.279	0.437	0.392	0.380	0.378	0.322	0.338	0.824	
Factor 9	0.521	0.322	0.338	0.482	0.306	0.279	0.448	0.355	0.191	0.352	0.823

- **Frequency table outputs from SPSS© for Non-technical skills**

Q2.1 Ability to maintain adequate situational awareness

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Extremely important	37	25.2	34.3	34.3
	Very important	47	32.0	43.5	77.8
	Moderately important	22	15.0	20.4	98.1
	Slightly important	2	1.4	1.9	100.0
	Total	108	73.5	100.0	
Missing	System	39	26.5		
Total		147	100.0		

Q2.2 Ability to execute planned decisions

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Extremely important	28	19.0	25.9	25.9
	Very important	45	30.6	41.7	67.6
	Moderately important	28	19.0	25.9	93.5
	Slightly important	6	4.1	5.6	99.1
	Not at all important	1	.7	.9	100.0
	Total	108	73.5	100.0	
Missing	System	39	26.5		
Total		147	100.0		

Q2.3 Ability to distribute and manage workload

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Extremely important	17	11.6	15.7	15.7
	Very important	47	32.0	43.5	59.3
	Moderately important	34	23.1	31.5	90.7
	Slightly important	6	4.1	5.6	96.3
	Not at all important	4	2.7	3.7	100.0
	Total	108	73.5	100.0	
Missing	System	39	26.5		
Total		147	100.0		

Q2.4 Ability for anticipatory thinking

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Extremely important	24	16.3	22.2	22.2
	Very important	47	32.0	43.5	65.7
	Moderately important	31	21.1	28.7	94.4
	Slightly important	5	3.4	4.6	99.1
	Not at all important	1	.7	.9	100.0
	Total	108	73.5	100.0	
Missing	System	39	26.5		
Total		147	100.0		

Q2.5 Ability to think creatively and develop novel solutions

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Extremely important	21	14.3	19.4	19.4
	Very important	40	27.2	37.0	56.5
	Moderately important	31	21.1	28.7	85.2
	Slightly important	14	9.5	13.0	98.1
	Not at all important	2	1.4	1.9	100.0
	Total	108	73.5	100.0	
Missing	System	39	26.5		
Total		147	100.0		

Q3.1 Ability to communicate effectively and being a good listener

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Extremely important	33	22.4	30.6	30.6
	Very important	48	32.7	44.4	75.0
	Moderately important	22	15.0	20.4	95.4
	Slightly important	3	2.0	2.8	98.1
	Not at all important	2	1.4	1.9	100.0
	Total	108	73.5	100.0	
Missing	System	39	26.5		
Total		147	100.0		

Q3.2 Ability to take leadership initiatives in both normal and abnormal situations

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Extremely important	41	27.9	38.0	38.0
	Very important	38	25.9	35.2	73.1
	Moderately important	24	16.3	22.2	95.4
	Slightly important	3	2.0	2.8	98.1
	Not at all important	2	1.4	1.9	100.0
	Total	108	73.5	100.0	
Missing	System	39	26.5		
Total		147	100.0		

Q3.3 Ability to perform as cohesive team member

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Extremely important	37	25.2	34.3	34.3
	Very important	38	25.9	35.2	69.4
	Moderately important	29	19.7	26.9	96.3
	Slightly important	2	1.4	1.9	98.1
	Not at all important	2	1.4	1.9	100.0
	Total	108	73.5	100.0	
Missing	System	39	26.5		
Total		147	100.0		

Q3.4 Ability to shift gears or change direction as needed to be flexible and adaptable

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Extremely important	28	19.0	25.9	25.9
	Very important	48	32.7	44.4	70.4
	Moderately important	28	19.0	25.9	96.3
	Slightly important	4	2.7	3.7	100.0
	Total	108	73.5	100.0	
Missing	System	39	26.5		
Total		147	100.0		

Q3.5 Ability to cope with work related stress

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Extremely important	38	25.9	35.2	35.2
	Very important	41	27.9	38.0	73.1
	Moderately important	26	17.7	24.1	97.2
	Slightly important	1	.7	.9	98.1
	Not at all important	2	1.4	1.9	100.0
	Total	108	73.5	100.0	
Missing	System	39	26.5		
Total		147	100.0		

Q3.6 Ability to build and maintain good relationships and develop rapport

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Extremely important	32	21.8	29.6	29.6
	Very important	55	37.4	50.9	80.6
	Moderately important	18	12.2	16.7	97.2
	Slightly important	2	1.4	1.9	99.1
	Not at all important	1	.7	.9	100.0
	Total	108	73.5	100.0	
Missing	System	39	26.5		
Total		147	100.0		

A.11 Outline of the analysis for paper-2

- Non-parametric Kruskal-Wallis test results for Q.1

Test Statistics[a,b]

	... send e-mail to a friend.
Kruskal-Wallis H	7.055
df	3
Asymp. Sig.	.070

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	... send e-mail to a friend.
Kruskal-Wallis H	1.667
df	3
Asymp. Sig.	.644

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.2

Test Statistics[a,b]

	... subscribe to a discussion list.
Kruskal-Wallis H	7.058
df	3
Asymp. Sig.	.070

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	... subscribe to a discussion list.
Kruskal-Wallis H	1.923
df	3
Asymp. Sig.	.589

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.3

Test Statistics[a,b]

	... create a distribution list to send e-mail to several people at once.
Kruskal-Wallis H	12.990
df	3
Asymp. Sig.	.005

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree

Test Statistics[a,b]

	... create a distribution to send e-mail to several people at once.
Kruskal-Wallis H	2.380
df	3
Asymp. Sig.	.497

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.4

Test Statistics[a,b]

	... send a document as an attachment to an e-mail message.
Kruskal-Wallis H	11.982
df	3
Asymp. Sig.	.007

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree

Test Statistics[a,b]

	... send a document as an attachment to an e-mail message.
Kruskal-Wallis H	4.286
df	3
Asymp. Sig.	.232

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.5

Test Statistics[a,b]

	... keep copies of outgoing messages that I send to others.
Kruskal-Wallis H	16.226
df	3
Asymp. Sig.	.001

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree

Test Statistics[a,b]

	... keep copies of outgoing messages that I send to others.
Kruskal-Wallis H	4.260
df	3
Asymp. Sig.	.235

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.6

Test Statistics[a,b]

	... use an Internet search engine (e.g., Google)
Kruskal-Wallis H	10.146
df	3
Asymp. Sig.	.017

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	... use an Internet search engine (e.g., Google)
Kruskal-Wallis H	1.614
df	3
Asymp. Sig.	.656

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.7

Test Statistics[a,b]

	... search for and find the Smithsonian Institution Web site.
Kruskal-Wallis H	9.017
df	3
Asymp. Sig.	.029

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	... search for and find the Smithsonian Institution Web site.
Kruskal-Wallis H	4.895
df	3
Asymp. Sig.	.180

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.8

Test Statistics[a,b]

	... create my own web page.
Kruskal-Wallis H	.990
df	3
Asymp. Sig.	.804

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	... create my own web page.
Kruskal-Wallis H	1.461
df	3
Asymp. Sig.	.691

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.9

Test Statistics[a,b]

	... keep track of Web sites I have visited so that I can return to them later.
Kruskal-Wallis H	10.534
df	3
Asymp. Sig.	.015

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	... keep track of Web sites I have visited so that I can return to them later.
Kruskal-Wallis H	2.505
df	3
Asymp. Sig.	.474

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.10

Test Statistics[a,b]

	... find primary sources of information on the Internet
Kruskal-Wallis H	14.630
df	3
Asymp. Sig.	.002

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	... find primary sources of information on the Internet
Kruskal-Wallis H	3.402
df	3
Asymp. Sig.	.334

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.11

Test Statistics[a,b]

	... use a spreadsheet to create a bar graph of the proportions of the different colors
Kruskal-Wallis H	8.805
df	3
Asymp. Sig.	.032

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	... use a spreadsheet to create a bar graph of the proportions of the different colors
Kruskal-Wallis H	2.817
df	3
Asymp. Sig.	.421

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.12

Test Statistics[a,b]

	... create a newsletter with graphics.
Kruskal-Wallis H	5.723
df	3
Asymp. Sig.	.126

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	... create a newsletter with graphics.
Kruskal-Wallis H	1.589
df	3
Asymp. Sig.	.662

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.13

Test Statistics[a,b]

	... save documents in formats so that others can read them
Kruskal-Wallis H	14.141
df	3
Asymp. Sig.	.003

a. Kruskal Wallis Test
b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	... save documents in formats so that others can read them
Kruskal-Wallis H	1.537
df	3
Asymp. Sig.	.674

a. Kruskal Wallis Test
b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.14

Test Statistics[a,b]

	…use the computer to create a slideshow presentation.
Kruskal-Wallis H	20.729
df	3
Asymp. Sig.	.000

a. Kruskal Wallis Test
b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	…use the computer to create a slideshow presentation.
Kruskal-Wallis H	3.116
df	3
Asymp. Sig.	.374

a. Kruskal Wallis Test
b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.15

Test Statistics[a,b]

	... create a database of information about important authors
Kruskal-Wallis H	8.361
df	3
Asymp. Sig.	.039

a. Kruskal Wallis Test
b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	... create a database of information about important authors
Kruskal-Wallis H	1.112
df	3
Asymp. Sig.	.774

a. Kruskal Wallis Test
b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.16

Test Statistics[a,b]

	…write an essay describing how I would use technology in my classroom.
Kruskal-Wallis H	9.109
df	3
Asymp. Sig.	.028

a. Kruskal Wallis Test
b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	…write an essay describing how I would use technology in my classroom.
Kruskal-Wallis H	4.277
df	3
Asymp. Sig.	.233

a. Kruskal Wallis Test
b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.17

Test Statistics[a,b]

	... create a lesson or unit that incorporates subject matter software as an integral part.
Kruskal-Wallis H	9.122
df	3
Asymp. Sig.	.028

a. Kruskal Wallis Test
b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	... create a lesson or unit that incorporates subject matter software as an integral part.
Kruskal-Wallis H	3.519
df	3
Asymp. Sig.	.318

a. Kruskal Wallis Test
b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.18

Test Statistics[a,b]

	... use technology to collaborate with teachers or students
Kruskal-Wallis H	11.822
df	3
Asymp. Sig.	.008

a. Kruskal Wallis Test
b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	... use technology to collaborate with teachers or students
Kruskal-Wallis H	3.415
df	3
Asymp. Sig.	.332

a. Kruskal Wallis Test
b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.19

Test Statistics[a,b]

	… describe 5 software programs or apps that I would use in my teaching.
Kruskal-Wallis H	13.021
df	3
Asymp. Sig.	.005

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	… describe 5 software programs or apps that I would use in my teaching.
Kruskal-Wallis H	3.225
df	3
Asymp. Sig.	.358

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.20

Test Statistics[a,b]

	... write a plan with a budget to buy technology for my classroom.
Kruskal-Wallis H	14.592
df	3
Asymp. Sig.	.002

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	... write a plan with a budget to buy technology for my classroom.
Kruskal-Wallis H	1.208
df	3
Asymp. Sig.	.751

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.21

Test Statistics[a,b]

	…integrate mobile technologies into my curriculum.
Kruskal-Wallis H	7.065
df	3
Asymp. Sig.	.070

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	…integrate mobile technologies into my curriculum.
Kruskal-Wallis H	1.146
df	3
Asymp. Sig.	.766

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.22

Test Statistics[a,b]

	…use social media tools for instruction in the classroom.
Kruskal-Wallis H	7.046
df	3
Asymp. Sig.	.070

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	…use social media tools for instruction in the classroom.
Kruskal-Wallis H	.672
df	3
Asymp. Sig.	.880

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.23

Test Statistics[a,b]

	…create a wiki or blog to have my students collaborate.
Kruskal-Wallis H	5.104
df	3
Asymp. Sig.	.164

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	…create a wiki or blog to have my students collaborate.
Kruskal-Wallis H	2.649
df	3
Asymp. Sig.	.449

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.24

Test Statistics[a,b]

	…use online tools to teach my students from a distance.
Kruskal-Wallis H	3.925
df	3
Asymp. Sig.	.270

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	…use online tools to teach my students from a distance.
Kruskal-Wallis H	1.490
df	3
Asymp. Sig.	.685

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.25

Test Statistics[a,b]

	…teach in a one-to-one environment
Kruskal-Wallis H	4.314
df	3
Asymp. Sig.	.229

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	…teach in a one-to-one environment.
Kruskal-Wallis H	4.170
df	3
Asymp. Sig.	.244

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.26

Test Statistics[a,b]

	…find a way to use a smartphone in my classroom
Kruskal-Wallis H	6.732
df	3
Asymp. Sig.	.081

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	…find a way to use a smartphone in my classroom
Kruskal-Wallis H	2.596
df	3
Asymp. Sig.	.458

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.27

Test Statistics[a,b]

	use mobile devices to connect to others for my professional development.
Kruskal-Wallis H	3.162
df	3
Asymp. Sig.	.367

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	use mobile devices to connect to others for my professional development.
Kruskal-Wallis H	3.981
df	3
Asymp. Sig.	.263

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.28

Test Statistics[a,b]

	… use mobile devices to have my students access learning activities.
Kruskal-Wallis H	4.831
df	3
Asymp. Sig.	.185

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	… use mobile devices to have my students access learning activities.
Kruskal-Wallis H	3.859
df	3
Asymp. Sig.	.277

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.29

Test Statistics[a,b]

	… download and listen to podcasts/audio books.
Kruskal-Wallis H	10.011
df	3
Asymp. Sig.	.018

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	… download and listen to podcasts/audio books.
Kruskal-Wallis H	2.386
df	3
Asymp. Sig.	.496

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.30

Test Statistics[a,b]

	… download and read e-books.
Kruskal-Wallis H	13.894
df	3
Asymp. Sig.	.003

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	… download and read e-books.
Kruskal-Wallis H	2.626
df	3
Asymp. Sig.	.453

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.31

Test Statistics[a,b]

	… download and view streaming movies/video clips.
Kruskal-Wallis H	6.441
df	3
Asymp. Sig.	.092

a. Kruskal Wallis Test
b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	… download and view streaming movies/video clips.
Kruskal-Wallis H	4.754
df	3
Asymp. Sig.	.191

a. Kruskal Wallis Test
b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.32

Test Statistics[a,b]

	… send and receive text messages.
Kruskal-Wallis H	9.311
df	3
Asymp. Sig.	.025

a. Kruskal Wallis Test
b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	… send and receive text messages.
Kruskal-Wallis H	4.702
df	3
Asymp. Sig.	.195

a. Kruskal Wallis Test
b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.33

Test Statistics[a,b]

	… transfer photos or other data via a smartphone.
Kruskal-Wallis H	7.505
df	3
Asymp. Sig.	.057

a. Kruskal Wallis Test
b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	… transfer photos or other data via a smartphone.
Kruskal-Wallis H	2.031
df	3
Asymp. Sig.	.566

a. Kruskal Wallis Test
b. Grouping Variable: Years of teaching experience

- Non-parametric Kruskal-Wallis test results for Q.34

Test Statistics[a,b]

	… save and retrieve files in a cloud-based environment.
Kruskal-Wallis H	7.308
df	3
Asymp. Sig.	.063

a. Kruskal Wallis Test

b. Grouping Variable: Highest degree received

Test Statistics[a,b]

	… save and retrieve files in a cloud-based environment.
Kruskal-Wallis H	1.230
df	3
Asymp. Sig.	.746

a. Kruskal Wallis Test

b. Grouping Variable: Years of teaching experience

- **Descriptive Statistics output from SPSS© for each of the item in TPSA-C21**

Descriptive Statistics

	N	Min	Max	Mean	Std. Deviation
... send e-mail to a friend.	62	2	5	4.74	.571
... subscribe to a discussion list.	62	3	5	4.68	.594
... create a distribution list to send e-mail to several people at once.	62	2	5	4.60	.689
... send a document as an attachment to an e-mail message.	62	3	5	4.81	.474
... keep copies of outgoing messages that I send to others.	62	3	5	4.73	.548
... use an Internet search engine (e.g., Google) to find Web pages related to my subject matter interests.	62	3	5	4.85	.399
... search for and find the Smithsonian Institution Web site.	62	1	5	4.60	.839
... create my own web page.	62	1	5	3.37	1.258
... keep track of Web sites I have visited so that I can return to them later. (An example is using bookmarks.)	62	1	5	4.56	.822
... find primary sources of information on the Internet that I can use in my teaching.	62	2	5	4.65	.655
... use a spreadsheet to create a bar graph of the proportions of the different colors of M&Ms in a bag.	62	1	5	4.26	1.023
... create a newsletter with graphics.	62	1	5	4.00	1.187
... save documents in formats so that others can read them if they have different word processing programs (eg., saving Word, pdf, RTF, or text).	62	1	5	4.60	.799
…use the computer to create a slideshow presentation.	62	3	5	4.81	.474

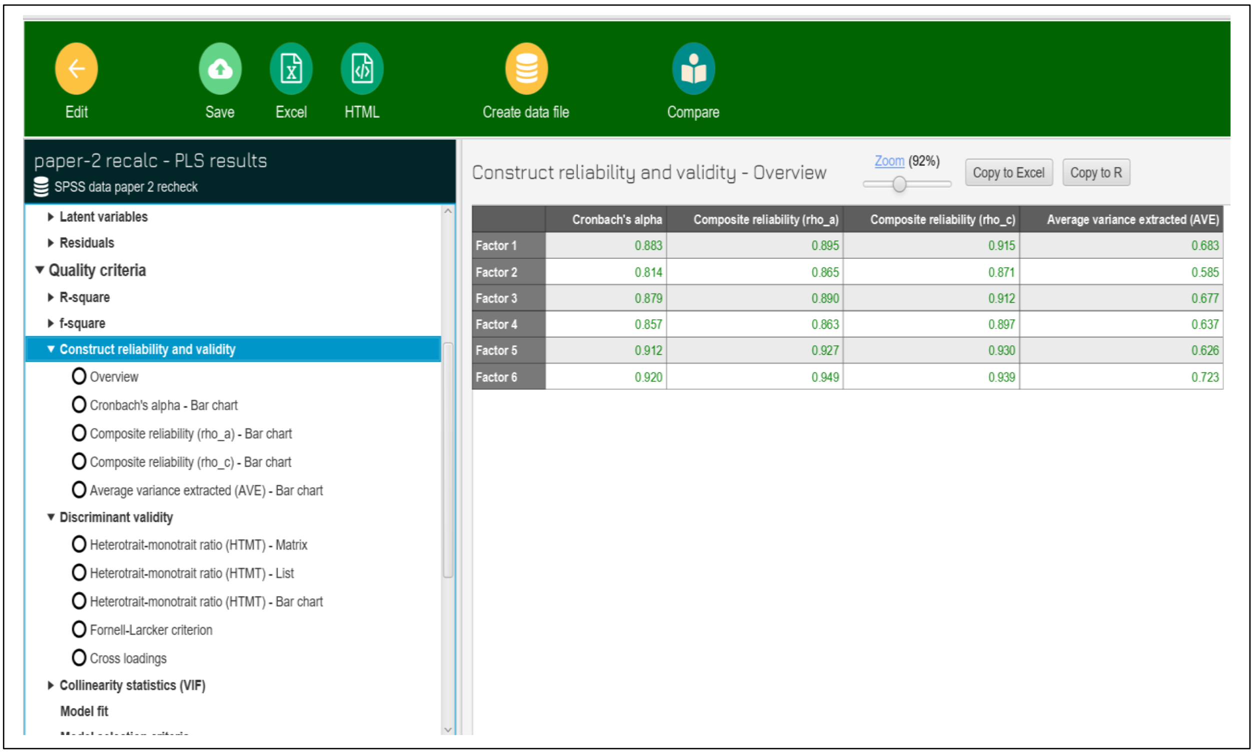
... create a database of information about important authors in a subject matter field.	62	1	5	4.08	1.029
…write an essay describing how I would use technology in my classroom.	62	2	5	4.45	.843
... create a lesson or unit that incorporates subject matter software as an integral part.	62	1	5	4.06	.973
... use technology to collaborate with teachers or students, who are distant from my classroom.	62	1	5	4.53	.718
… describe 5 software programs or apps that I would use in my teaching.	62	1	5	4.03	1.086
... write a plan with a budget to buy technology for my classroom.	62	1	5	4.10	1.020
…integrate mobile technologies into my curriculum.	62	1	5	4.11	.960
…use social media tools for instruction in the classroom. (ex. Facebook, Twitter, etc.)	62	1	5	3.47	1.457
…create a wiki or blog to have my students collaborate.	62	1	5	3.47	1.224
…use online tools to teach my students from a distance.	62	1	5	4.48	.805
…teach in a one-to-one environment in which the students have their own device.	62	2	5	4.44	.738
…find a way to use a smartphone in my classroom for student responses.	62	1	5	4.15	1.022
use mobile devices to connect to others for my professional development.	62	1	5	4.13	1.000
… use mobile devices to have my students access learning activities.	62	1	5	4.18	.967
… download and listen to podcasts/audio books.	62	1	5	4.42	.801
… download and read e-books.	62	1	5	4.48	.784
… download and view streaming movies/video clips.	62	1	5	4.56	.738
… send and receive text messages.	62	3	5	4.74	.477
… transfer photos or other data via a smartphone.	62	1	5	4.76	.619
… save and retrieve files in a cloud-based environment.	62	1	5	4.58	.737
Valid N (listwise)	62				

- **Factor loading output from SmartPLS4©**

Outer loadings - Matrix

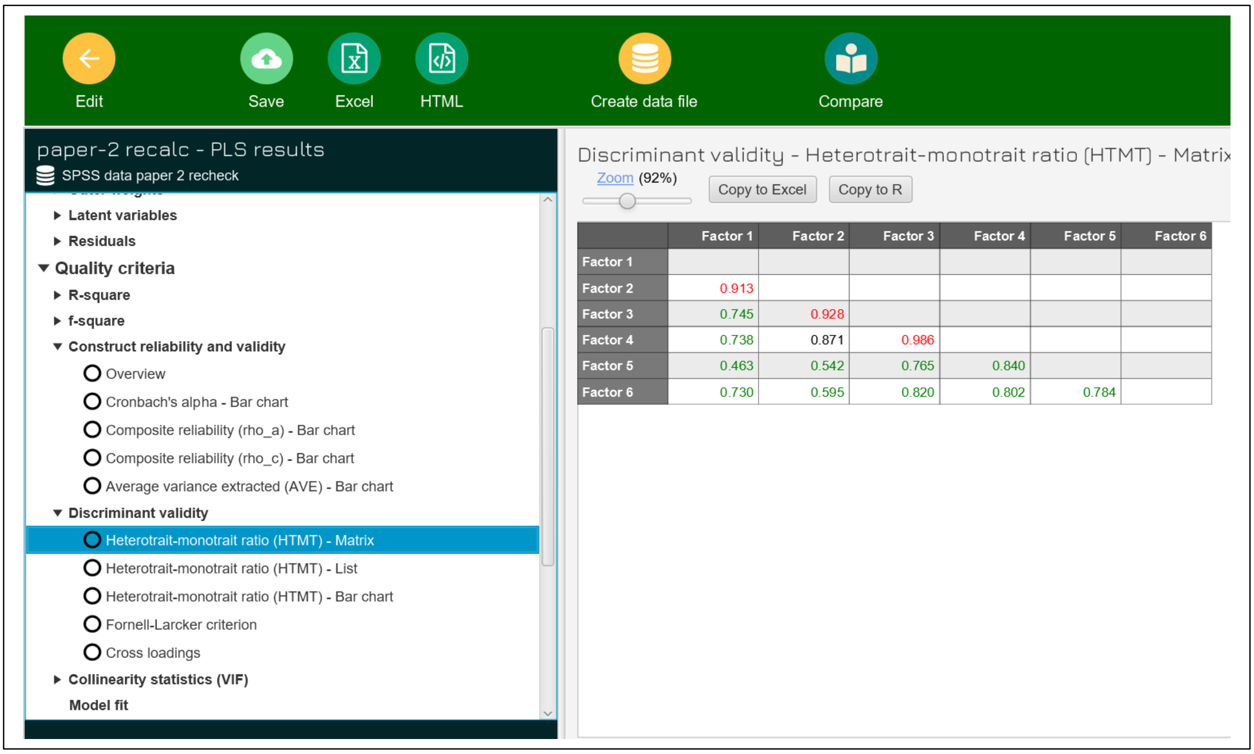
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Q1	0.767					
Q10		0.854				
Q11			0.879			
Q12			0.811			
Q13			0.884			
Q14			0.802			
Q15			0.726			
Q16				0.770		
Q17				0.855		
Q18				0.850		
Q19				0.732		
Q2	0.896					
Q20				0.777		
Q21					0.823	
Q22					0.616	
Q23					0.706	
Q24					0.814	
Q25					0.714	
Q26					0.883	
Q27					0.846	
Q28					0.885	
Q29						0.885
Q3	0.759					
Q30						0.915
Q31						0.908
Q32						0.573
Q33						0.892
Q34						0.876
Q4	0.860					
Q5	0.841					
Q6		0.713				
Q7		0.852				
Q8		0.464				
Q9		0.865				

- **Reliability statistics from SmartPLS4©**



	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Factor 1	0.883	0.895	0.915	0.683
Factor 2	0.814	0.865	0.871	0.585
Factor 3	0.879	0.890	0.912	0.677
Factor 4	0.857	0.863	0.897	0.637
Factor 5	0.912	0.927	0.930	0.626
Factor 6	0.920	0.949	0.939	0.723

- **Validity statistics from SmartPLS4©**



	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Factor 1						
Factor 2	0.913					
Factor 3	0.745	0.928				
Factor 4	0.738	0.871	0.986			
Factor 5	0.463	0.542	0.765	0.840		
Factor 6	0.730	0.595	0.820	0.802	0.784	

A.12 Outline of the analysis for paper-3

- Raw data after initial processing

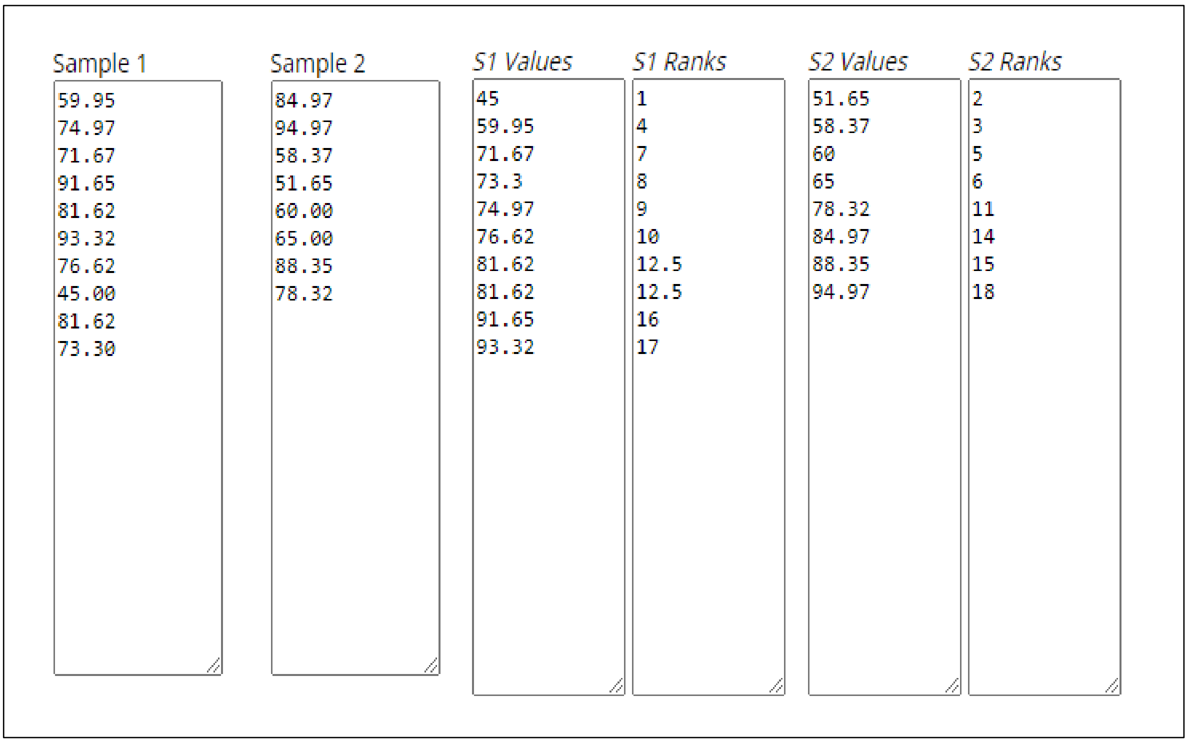
R#	Nav	Chtbt	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	Q.7	Q.8	Q.9	Q.10
				SUS data								
1	Y	Y	4.33	1.67	2.33	1.67	1.67	3.67	3.67	3.67	4.33	1.67
2	Y	N	3.00	1.00	4.33	1.00	2.33	1.00	3.67	3.00	4.33	1.67
3	Y	Y	3.67	1.67	3.67	1.67	3.67	1.67	3.00	2.33	4.33	2.33
4	Y	Y	3.67	1.67	5.00	1.00	4.33	1.67	5.00	1.00	5.00	1.00
5	Y	CS	4.33	1.67	4.33	1.00	2.33	3.00	5.00	1.67	5.00	1.00
6	Y	Y	4.33	1.00	5.00	1.00	3.67	1.67	5.00	1.00	5.00	1.00
7	Y	Y	3.00	2.33	4.33	1.00	3.00	1.67	4.33	1.67	4.33	1.67
8	N	Y	3.00	1.00	5.00	1.00	3.00	1.67	5.00	1.00	4.33	1.67
9	N	Y	4.33	1.00	4.33	1.00	5.00	1.67	5.00	1.00	5.00	1.00
10	Y	N	1.67	3.00	2.33	1.67	1.67	4.33	3.00	2.33	2.33	1.67
11	N	N	3.67	3.00	3.67	2.33	3.00	2.33	3.00	2.33	2.33	2.33
12	Y	N	5.00	1.67	4.33	1.00	2.33	1.67	5.00	3.00	4.33	1.00
13	N	Y	2.33	2.33	3.00	1.00	2.33	3.00	3.67	3.67	2.33	3.00
14	N	N	3.67	3.00	3.00	1.67	3.00	3.00	3.67	3.00	3.00	1.67
15	N	CS	3.67	2.33	4.33	1.00	3.67	3.00	4.33	3.00	3.00	3.67
16	N	Y	3.67	1.00	5.00	1.00	5.00	4.33	5.00	1.00	5.00	1.00
17	Y	Y	3.67	1.67	3.67	1.67	3.00	3.00	4.33	1.67	4.33	1.67
18	N	Y	3.00	1.67	4.33	1.00	3.67	2.33	4.33	1.67	5.00	2.33
		Mean	3.53	1.81	3.97	1.26	3.13	2.47	4.19	2.1	4.04	1.73

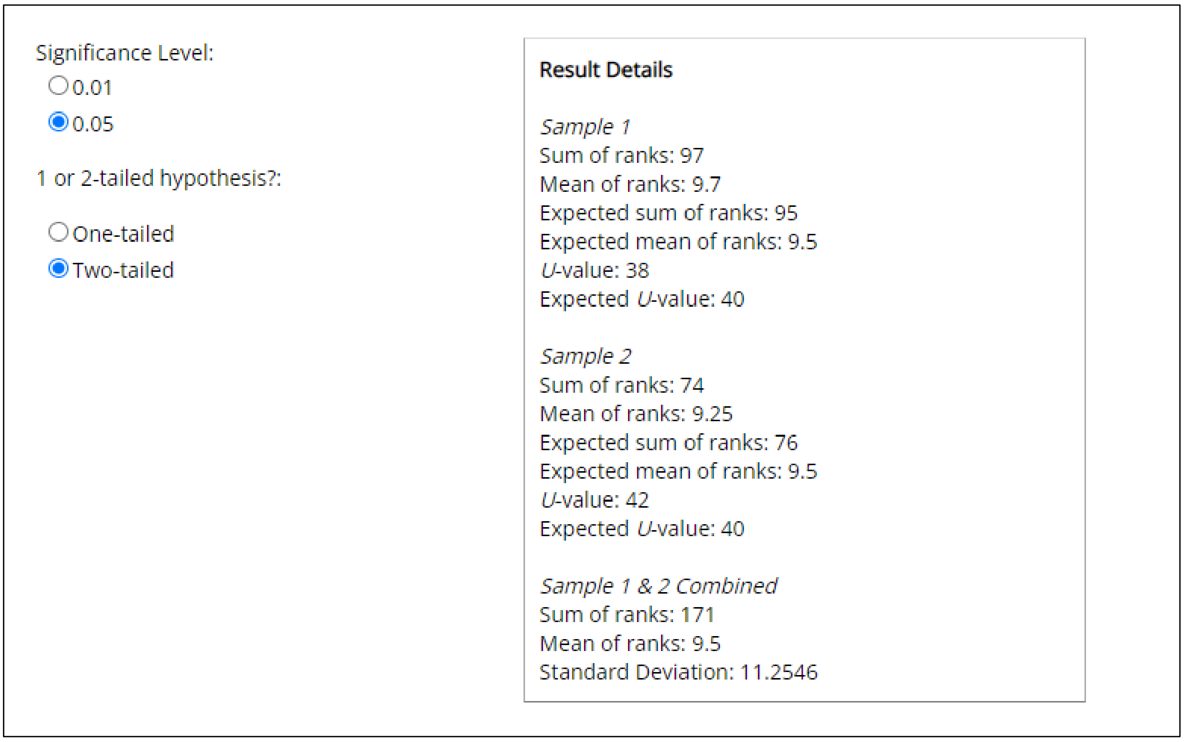
Abbreviation	
R#	Respondent number
Nav	Experience with navigation
Chtbt	Experience with chatbot
Y	Yes
N	No
CS	Cant say

- Comparison between group data using Mann-Whitney U Test

	Experience with		
Respondent number	Navigation	Chatbot	Final SUS
Respondent 1	Y	Y	59.95
Respondent 2	Y	N	74.97
Respondent 3	Y	Y	71.67
Respondent 4	Y	Y	91.65
Respondent 5	Y	CS	81.62
Respondent 6	Y	Y	93.32
Respondent 7	Y	Y	76.62
Respondent 8	N	Y	84.97
Respondent 9	N	Y	94.97
Respondent 10	Y	N	45.00
Respondent 11	N	N	58.37
Respondent 12	Y	N	81.62
Respondent 13	N	Y	51.65
Respondent 14	N	N	60.00
Respondent 15	N	CS	65.00
Respondent 16	N	Y	88.35
Respondent 17	Y	Y	73.30
Respondent 18	N	Y	78.32

- Mann-Whitney U test for “Experience in navigation”





The U-value is 38. The critical value of U at p < .05 is 17.

Therefore, the result is not significant at p < .05.

The Z-Score is 0.13328. The p-value is .89656. The result is not significant at $p < .05$.

- Mann-Whitney U test for "Experience with Chatbot"

Sample 1	Sample 2	*S1 Values*	*S1 Ranks*	*S2 Values*	*S2 Ranks*
59.95	74.97	51.65	2	45	1
71.67	81.62	59.95	4	58.37	3
91.65	45.00	71.67	7	60	5
93.32	58.37	73.3	8	65	6
76.62	81.62	76.62	10	74.97	9
84.97	60.00	78.32	11	81.62	12.5
94.97	65.00	84.97	14	81.62	12.5
51.65		88.35	15		
88.35		91.65	16		
73.30		93.32	17		
78.32		94.97	18		

Significance Level:

- 0.01
- 0.05 (selected)

1 or 2-tailed hypothesis?:

- One-tailed
- Two-tailed (selected)

Result Details

Sample 1
Sum of ranks: 122
Mean of ranks: 11.09
Expected sum of ranks: 104.5
Expected mean of ranks: 9.5
U-value: 21
Expected *U*-value: 38.5

Sample 2
Sum of ranks: 49
Mean of ranks: 7
Expected sum of ranks: 66.5
Expected mean of ranks: 9.5
U-value: 56
Expected *U*-value: 38.5

Sample 1 & 2 Combined
Sum of ranks: 171
Mean of ranks: 9.5
Standard Deviation: 11.0416

The U-value is 21. The critical value of U at $p < .05$ is 16.

Therefore, the result is not significant at $p < .05$.

The Z-Score is 1.53963. The p-value is .12356. The result is not significant at $p < .05$.

A.13 Outline of the analysis for paper-4

- **Descriptive statistics from SmartPLS4©**

Indicator data (original) - MV descriptives

Zoom (72%) Copy to Excel Copy to R

	Mean	Median	Observed min	Observed max	Standard deviation	Excess kurtosis	Skewness	Number of observations used
CI1	4.419	5.000	1.000	7.000	0.940	2.158	-0.803	234.000
CI2	4.474	5.000	1.000	7.000	0.948	1.588	-0.865	234.000
CI3	4.543	5.000	1.000	7.000	0.853	3.157	-1.009	234.000
CI4	4.432	5.000	1.000	7.000	0.846	1.139	-0.914	234.000
CI5	4.423	5.000	1.000	7.000	0.913	1.811	-0.669	234.000
CI6	4.410	5.000	1.000	7.000	0.962	3.183	-1.279	234.000
CP1	3.991	4.000	1.000	7.000	1.004	0.596	-0.161	234.000
CP2	4.026	4.000	1.000	7.000	1.037	0.645	-0.236	234.000
CP3	4.192	4.000	1.000	7.000	0.970	1.054	-0.536	234.000
CP4	4.141	4.000	1.000	6.000	0.957	0.988	-0.875	234.000
CP5	4.047	4.000	1.000	7.000	1.174	0.634	-0.267	234.000
CP6	4.064	4.000	1.000	7.000	1.113	0.673	-0.464	234.000
IN1	4.090	4.000	1.000	7.000	1.007	0.833	-0.131	234.000
IN2	4.265	4.000	1.000	7.000	1.037	1.525	-0.711	234.000
IN3	3.863	4.000	1.000	7.000	1.093	0.600	-0.279	234.000
IN4	3.829	4.000	1.000	7.000	1.108	0.519	-0.113	234.000
IN5	4.056	4.000	1.000	7.000	1.022	0.396	-0.305	234.000
IN6	4.085	4.000	1.000	7.000	1.091	0.708	-0.330	234.000
TO1	4.419	5.000	2.000	7.000	0.865	0.979	-0.087	234.000
TO2	4.628	5.000	1.000	7.000	0.989	3.649	-1.282	234.000
TO3	4.598	5.000	1.000	7.000	0.943	4.197	-1.485	234.000
TO4	4.397	5.000	1.000	7.000	1.004	1.808	-0.913	234.000
TO5	4.496	5.000	1.000	7.000	1.005	1.169	-0.814	234.000
TO6	4.261	4.500	1.000	7.000	1.112	1.305	-0.831	234.000

- **Factor loading output from SPSS©**

Factor – 1: Communication and Interaction skills (CI)

Factor – 2: Technical and operational skills (TO)

Factor – 3: Content creation and Production skills (CP)

Factor – 4: Information navigation and processing skills (IN)

Rotated Component Matrix[a]

	Component			
	1	2	3	4
TO1	,260	,614	,185	,109
TO2	,480	,664	,064	,081
TO3	,433	,682	,061	,114
TO4	,339	,687	,158	,233
TO5	,167	,599	,389	,178
TO6	,024	,699	,235	,157
IN1	,226	,264	-,055	,732
IN2	,344	,192	,208	,626
IN3	,060	,101	,221	,778
IN4	,053	,079	,302	,770
IN5	,378	,157	,441	,605
IN6	,332	,167	,461	,541
CI1	,710	,318	,122	,254
CI2	,766	,175	,275	,177
CI3	,846	,173	,169	,120
CI4	,754	,263	,227	,153
CI5	,573	,388	,248	,225
CI6	,662	,312	,239	,179
CP1	,293	,266	,528	,248

CP2	,247	,325	,587	,199
CP3	,585	,224	,448	,186
CP4	,493	,131	,621	,193
CP5	,170	,204	,758	,219
CP6	,140	,109	,740	,148

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

- The factor loadings (λ) for each item were used to calculate Average Variance Extracted (AVE) and Composite Reliability (CR)

$$\varepsilon = 1 - \lambda^2 \text{ (For each item)}$$

$$AVE = \Sigma\lambda^2 / 6 \quad (\Sigma\lambda^2 = \text{Sum of (square of) each factor loading})$$

$$CR = \Sigma\lambda^2 / \Sigma\lambda^2 + \Sigma\,\varepsilon$$

- Descriptive and reliability statistics from SPSS©

    - Technical and operational skills

Item Statistics

	Mean	Std. Deviation	N
I know how to adjust privacy setting	4.42	.867	234
I know how to turn off the location settings on my mobile device	4.63	.991	234
I know how to protect a mobile device (e.g. with a PIN, a screen pattern or a finger print)	4.60	.945	234
I know how to store photos, documents, contacts or other files in the cloud (e.g. Google Drive, iCloud)	4.40	1.006	234
I know how to use private browsing (e.g. incognito mode)	4.50	1.007	234
I know how to block unwanted pop-up messages or ads	4.26	1.114	234

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.849	.852	6

- Information navigation and processing skills

Item Statistics

	Mean	Std. Deviation	N
I know how to choose the best keywords for online search	4.09	1.009	234
I know how to find a website I have visited before	4.26	1.039	234
I know how to find information on a website no matter how it is designed	3.86	1.095	234
I know how to use advanced search functions in search engine	3.83	1.110	234
I know how to check if the information I find online is true	4.06	1.024	234
I know how to figure out if a website can be trusted	4.09	1.093	234

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.872	.872	6

- Communication and interaction skills

Item Statistics

	Mean	Std. Deviation	N
Depending on who I want to communicate with, I know which medium or tool to use (make a call, send a WhatsApp message, send an email, etc.)	4.42	.942	234
I know when to mute myself or disable video in online interactions	4.47	.950	234
I know which images and information of me it is OK to share online	4.54	.854	234
I know when it is appropriate and when it is not appropriate to use emoticons(e.g. smileys, emojis) or text speak or capital letters	4.43	.848	234
I know how to report negative content relating to me or a group to which I belong	4.42	.915	234
I know how to recognise when someone is being bullied online	4.41	.964	234

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.910	.911	6

- Content creation and production skills

Item Statistics

	Mean	Std. Deviation	N
I know how to create something which incorporates different digital media (images, music, video, GIFs)	3.99	1.006	234
I know how to edit existing online images, music and videos	4.03	1.040	234
I know how to ensure that many people will see what I put online	4.19	.972	234
I know how to change the things I put online depending on how other people react to it	4.14	.959	234
I know how to distinguish sponsored and non-sponsored content	4.05	1.176	234
I know when I am allowed to use content covered by copyright	4.07	1.115	234

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.857	.860	6

- **Confirmatory Factor Analysis (CFA) fit indices output from SPSS©**

Result (Default model)

Minimum was achieved
Chi-square = 597,751
Degrees of freedom = 246
Probability level = ,000

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	54	597,751	246	,000	2,430
Saturated model	300	,000	0		
Independence model	24	3633,620	276	,000	13,165

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	,063	,821	,782	,673
Saturated model	,000	1,000		
Independence model	,416	,184	,113	,169

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	,835	,815	,896	,882	,895
Saturated model	1,000		1,000		1,000
Independence model	,000	,000	,000	,000	,000

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	,078	,070	,086	,000
Independence model	,228	,222	,235	,000

Regression Weights: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
TO1	<---	TechOp	1,000				
TO2	<---	TechOp	1,411	,149	9,473	***	
TO3	<---	TechOp	1,392	,144	9,694	***	
TO4	<---	TechOp	1,495	,153	9,749	***	
TO5	<---	TechOp	1,192	,145	8,236	***	
TO6	<---	TechOp	1,155	,156	7,398	***	
IN1	<---	Inav	1,000				
IN2	<---	Inav	1,204	,144	8,338	***	
IN3	<---	Inav	1,232	,151	8,163	***	
IN4	<---	Inav	1,277	,154	8,292	***	
IN5	<---	Inav	1,511	,156	9,683	***	
IN6	<---	Inav	1,503	,161	9,315	***	
CI1	<---	Coin	1,000				
CI2	<---	Coin	1,043	,075	13,986	***	
CI3	<---	Coin	,941	,067	14,046	***	
CI4	<---	Coin	,929	,067	13,949	***	
CI5	<---	Coin	,897	,074	12,094	***	
CI6	<---	Coin	1,013	,077	13,199	***	
CP1	<---	Copro	1,000				
CP2	<---	Copro	1,078	,111	9,667	***	
CP3	<---	Copro	1,095	,105	10,395	***	
CP4	<---	Copro	1,143	,105	10,902	***	
CP5	<---	Copro	1,201	,126	9,536	***	
CP6	<---	Copro	,976	,118	8,290	***	

Standardized Regression Weights: (Group number 1 - Default model)

			Estimate
TO1	<---	TechOp	,624
TO2	<---	TechOp	,771
TO3	<---	TechOp	,797
TO4	<---	TechOp	,803
TO5	<---	TechOp	,640
TO6	<---	TechOp	,561
IN1	<---	Inav	,589
IN2	<---	Inav	,688
IN3	<---	Inav	,667
IN4	<---	Inav	,683
IN5	<---	Inav	,876
IN6	<---	Inav	,817
CI1	<---	Coin	,793
CI2	<---	Coin	,821
CI3	<---	Coin	,823
CI4	<---	Coin	,819
CI5	<---	Coin	,733
CI6	<---	Coin	,785
CP1	<---	Copro	,676
CP2	<---	Copro	,705
CP3	<---	Copro	,766
CP4	<---	Copro	,811
CP5	<---	Copro	,695
CP6	<---	Copro	,595

Covariances: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
TechOp	<-->	Inav	,199	,037	5,430	***	
Inav	<-->	Coin	,302	,049	6,159	***	
Coin	<-->	Copro	,404	,057	7,039	***	
TechOp	<-->	Coin	,317	,047	6,697	***	
TechOp	<-->	Copro	,260	,043	6,020	***	
Inav	<-->	Copro	,321	,052	6,144	***	

Correlations: (Group number 1 - Default model)

			Estimate
TechOp	<-->	Inav	,624
Inav	<-->	Coin	,684
Coin	<-->	Copro	,798
TechOp	<-->	Coin	,788
TechOp	<-->	Copro	,709
Inav	<-->	Copro	,799

Variances: (Group number 1 - Default model)

	Estimate	S.E.	C.R.	P	Label
TechOp	,291	,058	5,055	***	
Inav	,351	,074	4,736	***	
Coin	,557	,078	7,128	***	
Copro	,461	,082	5,630	***	
u1	,456	,046	9,960	***	
u2	,397	,045	8,865	***	
u3	,325	,038	8,498	***	
u4	,358	,043	8,388	***	
u5	,597	,060	9,887	***	
u6	,847	,083	10,196	***	
u7	,662	,065	10,208	***	
u8	,566	,058	9,794	***	
u9	,663	,067	9,902	***	
u10	,655	,067	9,824	***	
u11	,243	,034	7,077	***	
u12	,396	,046	8,521	***	
u13	,328	,035	9,352	***	
u14	,293	,032	9,038	***	
u15	,234	,026	9,003	***	
u16	,235	,026	9,060	***	
u17	,386	,039	9,811	***	
u18	,355	,038	9,429	***	
u19	,547	,056	9,800	***	
u20	,541	,056	9,623	***	
u21	,389	,043	9,100	***	
u22	,314	,037	8,497	***	
u23	,713	,074	9,692	***	
u24	,800	,079	10,149	***	

Squared Multiple Correlations: (Group number 1 - Default model)

	Estimate
CP6	,354
CP5	,482
CP4	,657
CP3	,587
CP2	,497
CP1	,457
CI6	,617
CI5	,538
CI4	,671
CI3	,678
CI2	,674
CI1	,629
IN6	,667
IN5	,767
IN4	,466
IN3	,446
IN2	,473
IN1	,346
TO6	,315
TO5	,410
TO4	,645
TO3	,635
TO2	,594
TO1	,390

9 Articles

Article 1

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ARTICLE

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Exploring technical and non-technical competencies of navigators for autonomous shipping

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ABSTRACT

The emergence of autonomous ship technologies has attracted a growing body of academic studies, regulatory discussions and exploration endeavours in recent years. With the introduction of new technology comes the need for the seafarers to be trained in its use. The purpose of this paper is 1) to examine the suitability of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) Table A-II/1 competence framework for navigators under Maritime Autonomous Surface Ship (MASS) operations, and 2) to propose future technical and non-technical competencies that will be needed in autonomous shipping era. A mixed method approach was adopted with collection of both quantitative and qualitative data through a survey instrument developed on the basis of the literature and current STCW Table A-II/1, in which the 66 Knowledge, Understanding & Proficiency (KUP) requirements for navigators were converted into measurement items. Statistical analysis of the data has aided in identifying a list of key technical and non-technical competence requirements for the navigators under MASS operations. The results can be used as an input for revision of the STCW competence requirements and to facilitate the preparation and implementation of novel training frameworks for autonomous shipping.

KEYWORDS

Competence; STCW; autonomy; autonomous shipping; seafarers; MASS

1. Introduction

Shipping industry is often recognized as the lifeline of global economy (Stopford 2009). Over 50,000 merchant ships operate globally to keep the flow of international trade and are manned by over 1.5 million seafarers with representation of virtually every nationality on the globe (ICS 2019). Merchant ships are recognized as high-value assets and some of the technologically sophisticated ships can cost up to 200 million USD while carrying a variety of cargo across the destinations that are necessary and vital to markets worldwide (ICS 2019). Any unexpected event or accident during ship operations could result not only in considerable financial consequences to all stakeholders in the supply chain, but also have the potentials to result in casualties, loss of life, and significant environmental, legal and reputational consequences (Kim, Nazir, and Øvergård 2016; Schröder-Hinrichs, Hollnagel, and Baldauf 2012). Naturally to cater for these issues, shipping community has come up with international frameworks and conventions which dictate various aspects of shipping such as design, operations, manning and training. In this regard, the global maritime authority for

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establishing the standards for safety, security and environmental performance of international shipping is the International Maritime Organization (IMO).

Among other considerations, it is important that the ships are operated by well skilled and qualified seafarers. The training requirements of the industry are oriented towards producing seafarers that can not only operate the ships in an efficient manner, but also give considerable regard to environment and safety. The International Convention on Standards of Training, Certification & Watchkeeping for Seafarers (STCW, 1978 as amended) and its associated Code—as the key instrument of IMO, outlines the qualification standards for officers and ratings for merchant ships globally (IMO 2011). While basic STCW certificates are a prerequisite for any seafarer serving onboard ships, the specific training requirements for different levels of responsibility (i.e., management, operational & support) as well as different ship types and departments are also listed in the STCW Code. STCW in its present form, applies a skill-based framework for training of seafarers. Such framework traces its roots in the apprenticeship model where the seafarer needs to demonstrate the Knowledge, Understanding and Proficiency (KUP) of a set of tasks to be deemed competent for a particular rank (Burke and Clott 2016). The convention has been revised after every few years (1995 & 2010) since its inception to be in line with the contemporary needs of the shipping industry. The need for periodic revision of the STCW Convention and its associated Code can be attributed to changing workplace demands and novel competency requirement with the advent of new technology.

Shipping industry at the moment is undergoing through a wave of increased automation and digitalization (Kitada et al. 2018), interest in autonomous and remotely-controlled ships is growing at a rapid speed globally (Mallam, Nazir, and Sharma 2020; Kim and Mallam 2020). The reasons to support the introduction of autonomous ships ranges from economic reasons through increased efficiency to safety considerations (Brandsæter and Knutsen 2018). Porathe, Prison, and Man (2014) outline four major reasons—improved work environment, cost reduction, reduction of emissions and increased safety—as the drive for adopting autonomous ships. The introduction of autonomous ships also has the potential to result in new modes of ship transportation than the ones existing at the moment.

However, with the new technology comes the need for the seafarers to be trained in its use. Therefore, a natural lag towards the new competence requirements and their implementation in the existing regulations for the shipping industry exists. IMO has launched a regulatory scoping exercise for the potential introduction of Maritime Autonomous Surface Ships (MASS) and defined 4 degrees of autonomous ship operations (IMO 2018), as illustrated in the following Figure 1.

In the context of autonomous ships, the skills and competence that are required for the seafarers in charge of navigational watch i.e. the navigators, is not sufficiently investigated. There is a need for

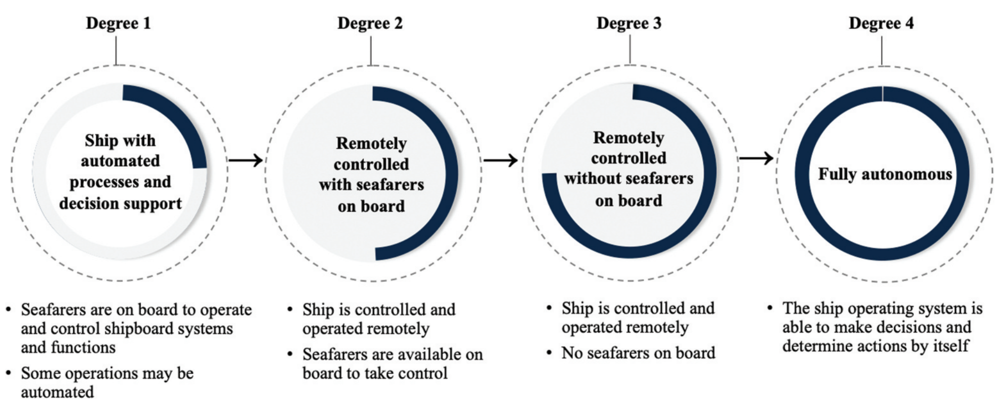

Figure 1. Degrees of autonomy as defined by IMO (adapted from IMO [2018]; Kim et al. 2019).

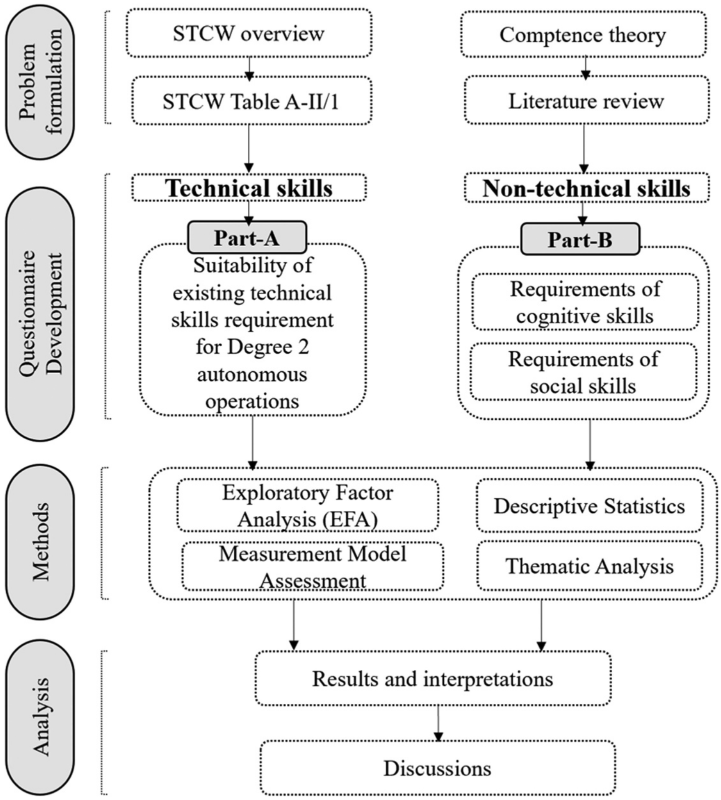

Figure 2. Research flow.

outlining of the needed competencies in order to correspondingly address the novel training requirements of the future navigators (Barsan, Hanzu-Pazara, and Arsenie 2007). It is expected that the STCW convention will be needed to be updated in coming years to catch up with the new operational environments of ships brought on by automation and digitalization. Several recent studies have discussed upon the issues regarding reskilling of seafarers and preparation of Maritime Education and Training (MET) institutes for meeting future competence demands for autonomous ship operations (Wright 2020; Emad, Khabir, and Shahbaksh 2020). However, none of the studies have conducted a detailed and itemized evaluation of the STCW competence requirements along with exploration regarding additional future skills. In this paper, we aim to investigate the suitability of the present STCW requirements (Table A-II/1) for Degree 2 MASS operations as defined by IMO (see Figure 1) and explore the novel future technical and non-technical competencies that will be required for navigators in merchant ships. The remainder of this manuscript is organized as follows —First, the concept of competency, skills requirement of navigators and historic development of STCW convention is elaborated upon. Next, the design of data collection instrument is described along with the data collection and analysis methods. Further, the obtained results are described in light of the selected research questions. Finally, the implications of the study are discussed for the shipping industry along with the future research directions.

2. Theoretical and legal background

There are several definitions and interpretations of the word 'competency' in the literature. A generic definition of competency as given by Oxford English dictionary is—'*the ability to do something successfully or efficiently*' (Stevenson 2010, 355). A more precise definition can be considered as the one given by United Nations Industrial Development Organization (UNIDO) which defines competency as—'*a set of skills encompassing knowledge and attributes which enables an individual to perform a task within a specific function/job effectively*' (Vathanophas and Thaingam 2007, 50). The research originating with regards to competency has conventionally described it in relation to the performance of the individual and to its surrounding environment. Woodruff (1993) described competency as '*the set of behavior patterns which are needed to allow the incumbent to perform tasks and functions with competence*'. Whereas Mace (2005) termed it as acquired personal skills which reflect potential ability to provide consistently adequate or high-level performance in a specific job function (Smythe et al. 2014, 60). The outlining and use of competency as a concept can therefore be seen as a part of the process to manage and improve the human performance in a given context through targeted education and training (Hoffmann 1999, 283). In relation to the above definitions, it is worth highlighting the difference between competency and skills. The term competency defines the requirements for the job in a broader context than skills. The terms such as skills, ability and knowledge therefore can be best termed as facets of competency in this regard. A navigator can be termed as competent if he/she can safely navigate the ship across two destinations safely. To undertake this task however, he/she will need a set of skills (e.g., passage planning, radar navigation).

The skills required by the navigators for the operation of ships can be broadly divided into—technical and non-technical skills (Hetherington, Flin, and Mearns 2006; Sharma et al. 2019). The technical skills refer to the knowledge regarding ship operations such as navigation, engine propulsion, cargo handling, maintenance and radio communications. Such skills can be ship specific and also change every few years due to basic changes in ship design and technology advancement. For instance, knowledge regarding use of various bridge equipment such as Electronic Chart Display and Information Systems (ECDIS), Global Positioning System (GPS), Radar, Automatic Radar Plotting Aid (ARPA), Automatic Identification System (AIS) have become paramount for present day navigators. The skills related to the navigational means of the past and the knowledge regarding them has either become obsolete or just present as superficial requirement (e.g. use of sextant to obtain fix) in assessment of competence. The future technical competencies of navigators will therefore, in part depend upon the development of novel navigational technologies and their subsequent adaption by ships.

In relation to the non-technical skills for navigators, the domain itself is relatively less explored by the stakeholders involved in MET. The first Bridge Resource Management (BRM) course for the maritime education and training purposes was launched in 1990s, taking inspiration from the aviation sector's Crew Resource Management (CRM) course (Barnett, Gatfield, and Pekcan 2003; O'Connor 2011). However, the effectiveness of BRM in terms of implementation and the outcomes has been reported variably (O'Connor 2011). Fjeld, Tvedt, and Oltedal (2018) in their review identified five non-technical skills in the research literature related to navigators: (1) situational awareness (2) workload management (3) decision making (4) communication and (5) leadership. It is worth noting that the first three belong to sub-category of 'cognitive skills' and the remaining 2 are classified as 'interpersonal (social) skills'. The investigation of more non-technical skills such as 'mental readiness', 'anticipatory thinking', 'coping with stress/fatigue' and 'seeking advice/feedback' as listed in taxonomy proposed by Yule et al. (2006) would be beneficial. In terms of cognitive skills and their facilitation, appropriate design considerations can help answer some of the concerns (Endsley and Kiris 1995). The acquisition of 'interpersonal' or 'social skills' in contrast would require active intervention in training of navigators.

Traditionally, maritime industry is termed as conservative (resistant to change) and reactive in nature (Mokashi, Wang, and Vermar 2002). The major conventions which regulate the maritime operations at present often originated as the aftermath of large-scale shipping disasters (Schröder-Hinrichs et al. 2013). In this regard, STCW convention is not different. The establishment of STCW was triggered by aftermath of the *Torrey Canyon and Amoco Cadiz* disaster, where the named ships grounded which resulted in the biggest environmental disasters at the time (Schröder-Hinrichs et al. 2013; Parsons and Allen 2018, 24). STCW upon its proposal and implementation initiated common framework for seafarer competence. It replaced the 1936 International Labour Organization (ILO) Officer Competency Certificate Convention (no.53) and was seen as a major step towards ensuring common competency standards worldwide (Morrison 1997). In the few years after its establishment, the shipping community however felt that the STCW 1978 missed its mark. Issues such as vague competence requirements interpreted differently by member states, lack of clarity in standards and continuing number of major shipping disasters meant that the member states signatory to the convention argued for major revisions (Emad and Roth 2008; Schröder-Hinrichs et al. 2013). These prevailing issues called for major revisions to the convention, which was adopted by IMO in the year 1995. The 1995 amendments to STCW marked a major change in the approach of IMO and shipping community with regards to establishment and compliance with safety related regulations in shipping. The member states were now required to demonstrate and outline clear road map of compliance than just being passive signatories as was the case in the past (Parsons and Allen 2018). The framing of regulations also laid emphasis on the importance of the human element within shipping rather than focusing on external provisions as was the norm of its predecessors. The STCW 1995 amendment among other major changes, laid out the Competence-Based Training (CBT) requirements for the seafarers. The competencies associated with specific job roles and profiles were now clearly documented, and the seafarers were required to demonstrate them before receiving certifications for their rank (Lewarn 2002).

The 2010 amendments to STCW continued the emphasis on proactive changes in education and training of seafarers with incorporation of new automation and digitalization developments within shipping. Several key competence requirements were added in this amendment, which were related to modern technologies such as ECDIS, work-rest hours regulations, security training, environmental awareness, and training in non-technical skills such as leadership and teamwork (IMO 2011). Currently, STCW 1978 as amended, in its Table A-II/1 has included 66 Knowledge, Understanding & Proficiency items (KUPs) which specifies the minimum standard of competence for officers in charge of navigational watch on ships of 500 gross tonnage or more (IMO 2011). These KUPs collectively reflect 19 competence themes as illustrated in Table 1.

Table 1. Competences for navigation officers in operational role as listed in Table A-II/1 of STCW (IMO, 2011, 99–110)

Competence themes
Plan and conduct a passage and determine position
KUP 1 Ability to use celestial bodies to determine the ship' position
KUP 2 Ability to determine the ship's position by use of 1) landmarks, 2) aids to navigation, including lighthouses, beacons and buoys, 3) dead reckoning, taking into account winds, tides, currents and estimated speed
KUP 3 Have thorough knowledge of and ability to use nautical charts, and publications, such as sailing directions, tide tables, notices to mariners, radio navigational warnings and ships' routing information
KUP 4 Ability to determine the ship's position by use of electronic navigational aids
KUP 5 Ability to operate the equipment and apply the information correctly
KUP 6 Have knowledge of the principles of magnetic and gyro-compasses
KUP 7 Ability to determine errors of the magnetic and gyro-compasses, using celestial and terrestrial means, and to allow for such errors
KUP 8 Have knowledge of steering control systems, operational procedures and change-over from manual to automatic control and vice versa. Adjustment of controls for optimum performance
KUP 9 Ability to use and interpret information obtained from shipborne meteorological instruments
KUP 10 Have knowledge of the characteristics of the various weather systems, reporting procedures and recording systems
KUP 11 Ability to apply the meteorological information available

(*Continued*)

Table 1. Competences for navigation officers in operational role as listed in Table A-II/1 of STCW (IMO, 2011, 99–110)

Maintain a safe navigational watch
KUP 12 Have thorough knowledge of the content, application and intent of the International Regulations for Preventing Collisions at Sea, 1972, as amended
KUP 13 Have thorough knowledge of the Principles to be observed in keeping a navigational watch
KUP 14 Proficient in use of routing in accordance with the General Provisions on ships' routing
KUP 15 Proficient in use of information from navigational equipment for maintaining a safe navigational watch
KUP 16 Have knowledge of blind pilotage techniques
KUP 17 Proficient in use of reporting in accordance with the General Principles for Ship Reporting Systems and with VTS procedures
KUP 18 Knowledge of bridge resource management principles, including 1) allocation, assignment, and prioritization of resources, 2) effective communication 3) assertiveness and leadership, 4) obtaining and maintaining situational awareness, 5) consideration of team experience
Use of radar and ARPA to maintain safety of navigation
KUP 19 Have knowledge of the fundamentals of radar and automatic radar plotting aids (ARPA)
KUP 20 Ability to operate and to interpret and analyse information obtained from radar and ARPA performance, including 1) factors affecting performance and accuracy, 2) setting up and maintaining displays, 3) detection of misrepresentation of information, false echoes, sea return, etc., racons and SARTs
KUP 21 Ability to operate and to interpret and analyse information obtained from radar and ARPA use, including 1) range and bearing; course and speed of other ships; time and distance of closest approach of crossing, meeting overtaking ships, 2) identification of critical echoes; detecting course and speed changes of other ships; effect of changes in own ship's course or speed or both, 3) application of the International Regulations for Preventing Collisions at Sea, 1972, as amended, 4) plotting techniques and relative- and true- motion concepts, 5) parallel indexing
KUP 22 Awareness of principal types of ARPA, their display characteristics, performance standards and the dangers of over-reliance on ARPA
KUP 23 Ability to operate and to interpret and analyse information obtained from ARPA, including 1) system performance and accuracy, tracking capabilities and limitations, and processing delays, 2) use of operational warnings and system tests, 3) methods of target acquisition and their limitations, 4) true and relative vectors, graphic representation of target information and danger areas, 5) deriving and analysing information, critical echoes, exclusion areas and trial manoeuvres
Use of ECDIS to maintain the safety of navigation
KUP 24 Have knowledge of the capability and limitations of ECDIS operations, including 1) a thorough understanding of Electronic Navigational Chart (ENC) data, data accuracy, presentation rules, display options and other chart data formats, 2) the dangers of over-reliance, 3) familiarity with the functions of ECDIS required by performance standards in force
KUP 25 Proficient in operation, interpretation, and analysis of information obtained from ECDIS, including 1) use of functions that are integrated with other navigation systems in various installations, including proper functioning and adjustment to desired settings, 2) safe monitoring and adjustment of information, including own position, sea area display, mode and orientation, chart data displayed, route monitoring, user-created information layers, contacts (when interfaced with AIS and/or radar tracking) and radar overlay functions (when interfaced), 3) confirmation of vessel position by alternative means, 4) efficient use of settings to ensure conformance to operational procedures, including alarm parameters for anti-grounding, proximity to contacts and special areas, completeness of chart data and chart update status, and backup arrangements, 5) adjustment of settings and values to suit the present conditions, 6) situational awareness while using ECDIS including safe water and proximity of hazards, set and drift, chart data and scale selection, suitability of route, contact detection and management, and integrity of sensors.
Respond to emergencies
KUP 26 Ability to take precautions for the protection and safety of passengers in emergency situations
KUP 27 Ability to take initial actions following a collision or a grounding; and ability to assess initial damage and perform control
KUP 28 Appreciate the procedures to be followed for rescuing persons from the sea, assisting a ship in distress, responding to emergencies which arise in port
Respond to a distress signal at sea
KUP 29 Have knowledge of the contents of the International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual
Use the IMO Standard Marine Communication Phrases and use English in written and Oral form
KUP 30 Have adequate knowledge of the English language to enable the officer to use charts and other nautical publications, to understand meteorological information and messages concerning ship's safety and operation, to communicate with other ships, coast stations and VTS centres and to perform the officer's duties also with a multilingual crew, including the ability to use and understand the IMO Standard Marine Communication Phrases (IMO SMCP)
Transmit and receive information by visual signalling
KUP 31 Ability to use the International Code of Signals
KUP 32 Ability to transmit and receive, by Morse light, distress signal SOS as specified in Annex IV of the International Regulations for Preventing Collisions at Sea, 1972, as amended, and appendix 1 of the International Code of Signals, and visual signalling of single-letter signals as also specified in the International Code of Signals
Manoeuvre the ship

(*Continued*)

Table 1. Competences for navigation officers in operational role as listed in Table A-II/1 of STCW (IMO, 2011, 99–110)

KUP 33 Have knowledge of ship manoeuvring and handling, including knowledge of 1) the effects of deadweight, draught, trim, speed and under-keel clearance on turning circles and stopping distances, 2) the effects of wind and current on ship handling, 3) manoeuvres and procedures for the rescue of person overboard, 4) squat, shallow-water and similar effects, 5) proper procedures for anchoring and mooring
Monitor the loading, stowage, securing, care during the voyage and the unloading of cargoes
KUP 34 Have knowledge of the effect of cargo, including heavy lifts, on the seaworthiness and stability of the ship
KUP 35 Have knowledge of safe handling, stowage and securing of cargoes, including dangerous, hazardous and harmful cargoes, and their effect on the safety of life and of the ship
KUP 36 Ability to establish and maintain effective communications during loading and unloading
Inspect and report defects and damage to cargo spaces, hatch covers and ballast tanks
KUP 37 Have knowledge and ability to explain where to look for damage and defects most commonly encountered due to 1) loading and unloading operations, 2) corrosion, 3) severe weather conditions
KUP 38 Ability to state which parts of the ship shall be inspected each time in order to cover all parts within a given period of time
KUP 39 Ability to identify those elements of the ship structure which are critical to the safety of the ship
KUP 40 Ability to state the causes of corrosion in cargo spaces and ballast tanks and how corrosion can be identified and prevented
KUP 41 Have knowledge of procedures on how the inspections shall be carried out
KUP 42 Ability to explain how to ensure reliable detection of defects and damages
KUP 43 Have understanding of the purpose of the 'enhanced survey programme'
Ensure compliance with pollution prevention requirements
KUP 44 Have knowledge of the precautions to be taken to prevent pollution of the marine environment
KUP 45 Awareness of anti-pollution procedures and all associated equipment
KUP 46 Awareness of importance of proactive measures to protect the marine environment
Maintain seaworthiness of the ship
KUP 47 Have working knowledge and application of stability, trim and stress tables, diagrams and stress-calculating equipment
KUP 48 Have understanding of fundamental actions to be taken in the event of partial loss of intact buoyancy
KUP 49 Have understanding of the fundamentals of watertight integrity
KUP 50 Have general knowledge of the principal structural members of a ship and the proper names for the various parts
Prevent, control and fight fires onboard
KUP 51 Ability to organize fire drills
KUP 52 Have knowledge of classes and chemistry of fire
KUP 53 Have knowledge of fire-fighting systems
KUP 54 Have knowledge of action to be taken in the event of fire, including fires involving oil systems
Operate life-saving appliances
KUP 55 Ability to organize abandon ship drills and knowledge of the operation of survival craft and rescue boats, their launching appliances and arrangements, and their equipment, including radio life-saving appliances, satellite EPIRBs, SARTs, immersion suits and thermal protective aids
Apply medical first onboard ship
KUP 56 Awareness of the practical application of medical guides and advice by radio, including the ability to take effective action based on such knowledge in the case of accidents or illnesses that are likely to occur on board ship
Monitor compliance with legislative requirements
KUP 57 Have basic working knowledge of the relevant IMO conventions concerning safety of life at sea, security and protection of the marine environment
Application of leadership and teamworking skills
KUP 58 Have working knowledge of shipboard personnel management and training
KUP 59 Have knowledge of related international maritime conventions and recommendations, and national legislation
KUP 60 Ability to apply task and workload management, including 1) planning and co-ordination, 2) personnel assignment, 3) time and resource constraints, 4) prioritization
KUP 61 Have knowledge and ability to apply effective resource management, including 1) allocation, assignment, and prioritization of resources, 2) effective communication onboard and ashore, 3) decisions reflect consideration of team experiences, 4) assertiveness and leadership, including motivation, 5) obtaining and maintaining situational awareness
KUP 62 Have knowledge and ability to apply decision-making techniques, including 1) situation and risk assessment, 2) identify and consider generated options, 3) selecting course of action, 4) evaluation of outcome effectiveness
Contribute to the safety of personnel and ship
KUP 63 Have knowledge of personal survival techniques
KUP 64 Have knowledge of fire prevention and ability to fight and extinguish fires
KUP 65 Have knowledge of elementary first aid
KUP 66 Have knowledge of personal safety and social responsibilities

Extrapolating the trends in shipping and taking into account the continuous automation of many functions onboard, some of the existing competence requirements listed above are bound to become obsolete (Sharma et al. 2019; Kim and Mallam 2020). On the other hand, new competence will be required to ensure the navigators are trained for the new job functions.

Furthermore, with gradual introduction of automation technologies onboard ships over the years, many of the ship's functions have already become automated. This has meant that ship owners who are responsible for manning and maintenance of ship would feel suffice to reduce the crew size, as crewing bears a significant cost in day-to-day ship operations (Stopford 2009). However, this has also meant that there are less and less crew onboard performing the duties on ships, but more information elements for the crew to process in a variety of operations. This has contributed to increased cognitive load, and it has been documented that many accidents in shipping have occurred not despite the presence of new technology but rather because of it (Lützhöft and Dekker 2002). The skillsets such as creative thinking, resilience, communication, leadership and management skills, as well as other cognitive and social skills have therefore become increasingly desired in the ship crew, in addition to their updated technical knowledge.

In light of above, the list of competence themes for ship navigators in Table 1 and the important cognitive and social skills as identified in the literature became the basis for designing a survey instrument, which was utilized in data collection and interpretation process of the present study.

3. Methods

To adequately model the competence requirements for navigators engaged in Degree 2 MASS operations, a mixed method approach was adopted. This consisted of a quantitative evaluation of the existing STCW competence framework, and a qualitative exploration of future technical and non-technical competencies navigators need to thrive in the era of autonomous shipping. The scope of the study was narrowed down to only include the navigators in operational role and hypothetically engaged in Degree 2 MASS operations scenario as illustrated in Figure 1. The IMO definition of autonomous shipping was used as a reference in the survey due to the international profile of the respondents. The aforementioned 66 KUPs in STCW 1978 as amended were converted into measurement items in a survey, where respondents were asked to rate the extent to which they think that autonomous shipping will impact on these KUPs and their requirement on a Likert scale from 1 (Extremely important) to 5 (Not at all important). The text content of the KUPs were not modified rather, the original text from STCW was followed in order to maintain the originality of the requirements and validity concerns of the study. The questionnaire was digitalized using the platform Qualtrics™, and the link was then sent out to respondents working on international merchant shipping industry through non-random & purposive sampling approach using professional network. The respondents either consisted of active seafarers or individuals working within shipping industry in some capacity. The collected data was exported from Qualtrics™ in the form of MS Excel Comma Separated Value (CSV) data file and was checked for blank and straight lining responses as part of data cleaning and preparation process. 43 cases of blank and 1 case of straight lining responses were found and consequently removed from dataset. A total number of 109 valid responses out of 153 collected responses were therefore registered for the comprehensive questionnaire. Several demographic questions were also included at the end of the questionnaire to facilitate the understanding of survey responses. The demographics data was collected for all the respondents except 2 cases of missing values, where the respondents completed the actual survey but erroneously left out the demographic information. The demographic characteristics of the respondents are summarized in Table 2.

In addition, the respondents were also asked to rate the importance of non-technical skills as identified in literature review about their relevance in Degree 2 autonomous operations. For this purpose, a separate section for non-technical skills was added in the survey questionnaire. The non-technical skills were further divided into cognitive and interpersonal (social) skills. Finally, an open-ended avenue provided in the survey questionnaire enabled the respondents to register qualitative responses about their opinion regarding which future technical and non-technical competencies

Table 2. Demographic characteristics of the respondents.

Range		Frequency	Percent
Industrial area	Shipping company	75	70.0
	Shipping management company	11	10.3
	Maritime training institute/provider	13	12.3
	Others	8	7.4
Shipping sectors	Wet Bulk (Tanker sector)	57	53.3
	Dry Bulk	8	7.4
	Cargo Liners and Container Ships	20	18.7
	Passenger Liners/Cruise Ships/Ferries	4	3.7
	Other shipping sectors	18	16.9
Year of experience	0–5 years	68	63.5
	6–10	14	13.1
	11–15	7	6.5
	+ 15 years	18	16.9

will be relevant. The survey utilized an anonymous link with no personal information being collected. For the quantitative section, the collected responses were analysed using following software and programs—SPSS™ and SmartPLS™. The questionnaire was designed using 'forced responses' function for the listed KUPs, so that there are no missing values and the respondents had to complete all the answers before proceeding further. The overall research flow is illustrated in the following Figure 2.

The collected responses were analysed using four modes of analysis: (1) Exploratory Factor Analysis (EFA) (2) Measurement Model Assessment (3) Descriptive Statistics and (4) Thematic Analysis. EFA is a multivariate statistical technique for quantitative analyses, which reduces the large number of variables into smaller set of factors that represent the sets of correlated variables (Kilner 2004; Tabachnick, Fidell, and Ullman 2007). EFA allows the researchers to undertake parsimonious analysis, generate theory and also evaluate the construct validity of the measurement instrument (Williams, Onsman, and Brown 2010). The data gathered regarding the evaluation of 66 KUPs were analysed using EFA to allow rigorous analysis for suitability and regrouping for Degree 2 MASS operations. Furthermore, the extracted factor structure from EFA was evaluated using partial least squares structural equation modelling technique for measurement model assessment as per the steps given by Hair et al (2019; 2020) to check for consistency, convergent and divergent validity of the indicators.

The qualitative responses gathered through the open-ended section of the questionnaire was subject to a detailed thematic analysis to identify the relevant themes. Braun and Clarke (2006, 79) defined thematic analysis as '*a method for identifying, analysing and reporting patterns (themes) within data*'. In this regard, a theme represents some level of 'patterned' response or meaning within the dataset. The emerging competence themes were categorized and coded. After the coding of emerging competence themes, only those not previously discussed in either STCW competence framework regarding technical skills or in the reviewed literature associated with non-technical skill requirements for navigators were qualified. As a result, any redundant competence theme was excluded. Finally, the data gathered for non-technical skills was subjected to descriptive analyses to better understand and visualize their relevancy as rated by the respondents.

4. Results

In accordance with described research framework, the results are reported in two parts. Part A describes the results regarding suitability of existing STCW competence framework and the requirement of novel technical skills obtained by EFA, measurement model assessment and thematic analysis, whereas Part B describes the descriptive statistics regarding the requirement of novel non-technical competence themes derived through thematic analysis.

4.1. Part-A

A Principal Component Analysis (PCA) was conducted on the 66 questionnaire items with varimax rotation. The Kaiser-Meyer-Olkin (KMO) value (.754), is above recommend value of 0.5 (Hair et al. 2006). Bartlett's test of sphericity was also significant ($p < 0.001$), which indicates a good level of sampling adequacy for the purpose of EFA. 28 KUPs out of 66 have obtained a score of < 2 from the scale of 1 (Extremely important) to 5 (Not important at all), which indicated their high relevance for Degree 2 MASS operations. The authors examined the factor loading of all items and removed the items that did not loaded significantly (<0.5) on any of the major components. Several iterations were run to determine the final factor structure. As given in the following Table 3, the final EFA has given 11 factors with eigenvalue greater than 1, which explained 72.6% of the total variance.

Factor 1 represents the KUPs 1, 2, 3, 6, 7 & 15. Examining the individual KUPs and the original theme as designated in Table 1, the derived competence theme was labelled as—*Position fixing & Watchkeeping*. Factor 2 contained KUPs 38–42, which are originally belonging to the theme—*Inspect and report defects and damages to cargo spaces, hatch covers and the ballast tanks*. Since all

Table 3. Results from Exploratory Factor Analysis (n= 109).

No.	Competence theme	Factor description	Loading	Comm. *	Cronbach's α
1	Position fixing & Watchkeeping	KUP 3	.800	.692	.830
		KUP 2	.743	.718	
		KUP 1	.736	.705	
		KUP 6	.701	.646	
		KUP 15	.621	.712	
		KUP 7	.593	.665	
2	Inspect and report defects and damages to cargo spaces, hatch covers & ballast tanks	KUP 40	.748	.747	.849
		KUP 39	.724	.712	
		KUP 41	.689	.724	
		KUP 42	.672	.712	
		KUP 38	.661	.600	
3	Prevent, control and fight fires onboard	KUP 52	.782	.820	.829
		KUP 54	.777	.764	
		KUP 53	.776	.827	
		KUP 51	.620	.590	
4	Contribute to safety of personnel and ship	KUP 63	.780	.683	.851
		KUP 65	.754	.735	
		KUP 64	.680	.747	
		KUP 66	.615	.683	
5	Use of radar, ARPA and ECDIS to maintain safety of navigation	KUP 24	.798	.711	.819
		KUP 22	.738	.770	
		KUP 23	.706	.675	
		KUP 25	.667	.646	
6	Application of leadership and teamworking skills	KUP 61	.809	.772	.823
		KUP 60	.741	.773	
		KUP 58	.678	.666	
		KUP 62	.629	.684	
7	Ensure compliance with pollution prevention	KUP 46	.884	.853	.880
		KUP 45	.841	.832	
		KUP 44	.809	.788	
8	Damage control and distress communication	KUP 28	.812	.796	.753
		KUP 27	.764	.717	
		KUP 29	.635	.642	
9	Application of meteorological information in navigation	KUP 11	.713	.758	.758
		KUP 10	.697	.731	
		KUP 9	.612	.672	
10	Reporting and communication	KUP 31	.788	.782	.622
		KUP 17	.762	.723	
11	Manoeuvring and maintaining seaworthiness of ship	KUP 33	.767	.774	.617
		KUP 47	.686	.789	

but 2 KUPs (37 & 43) were loaded on this factor, the original competence theme was retained after evaluation from the authors.

Comm.* refers to communalities, which indicate the amount of the variance in the variable that has been extracted by the factor solution. Varimax rotation performed to extract factors.

Factor 3 consisted of KUPs 51–54, which overlapped with the original competence theme titled *Prevent, control and fight fires onboard*, therefore the original title was retained. Factor 4 is made up of KUPs 63–66 and overlapped with the theme—*Contribute to safety of personnel and ship*, the original competence theme title was retained. Factor 5 consisted of KUPs 22–25. It has partial overlap with two competence themes, which are—*Use of radar and ARPA to maintain safety of navigation* and *Use of ECDIS to maintain safety of navigation*. Upon examining the individual KUPs that loaded on this factor, the competence theme was labelled as—*Use of radar, ARPA and ECDIS to maintain safety of navigation*. Factor 6 contained the KUPs 58, 60, 61 & 62. They barring for 1 KUP largely fall under the theme—*Application of leadership & teamworking skills* and the original competence theme was retained. Factor 7 consisted of KUPs 44, 45 & 46. It had a perfect overlap with the original competence theme—*Ensure compliance with pollution prevention requirements* and the title was retained. Factor 8 consisted of KUPs 27, 28 & 29, which have an overlap between two of the original themes, namely—*Respond to emergencies and Respond to a distress signal at sea*. Upon examining the individual KUPs, the competence theme was renamed as—*Damage control and distress communication*. Factor 9 consisted of KUPs 9, 10 & 11. After considering the individual KUPs, the competence theme was named as—*Application of meteorological information in navigation*. Factor 10 contained KUPs 17 & 31. Upon examining the individual KUPs the competence theme was labelled as—*Reporting and Communication*. Finally, Factor 11 consisted of KUP 33 & 47. The competence theme was labelled as—*Manoeuvring and maintaining seaworthiness of ship*. A reliability check for the synthesized factors was performed in SPSS^{TM} using the score of Cronbach's alpha as a measure. Cronbach's alpha score provides an indication of internal consistency of the measurement i.e. to which extent the items in the instrument measure the same construct (Tavakol and Dennick 2011). The overall Cronbach's alpha for total scale was 0.923. The Cronbach's alpha for each individual competence theme is shown in Table 3.

For measurement model assessment which is confirmatory in nature, the software package SmartPLS^{TM} was utilized and the results were checked against the guidelines provided by Hair et al. (2019) for reflexive measurement models regarding item loadings, internal consistency reliability, convergent and divergent validity. The first step in reflexive model assessment pertains to examining the indicator loadings. The following reflexive indicator loadings were obtained for the measurement model which barring for two items (KUP 1 & 2) had values above the recommended value of 0.708 as given in Table 4. These denote the indicator variance that is explained by the extracted factor.

Subsequently, the Composite Reliability (CR) and the Average Variance Extracted (AVE) values were calculated. The CR and AVE values for the factors in the measurement model are also provided in Table 4. The CR values for the extracted factors were ranging between 0.828 and 0.925, considered 'satisfactory to good' as per the guidelines (Hair et al. 2019). The obtained Average Variance Extracted (AVE) values, except Factor 1, were greater than recommended threshold of 0.5 (Hair, Howard, and Nitzl 2020). Finally, the discriminant validity, using the Fornell-Larcker criterion was calculated. As reported in Table 5, square root of each factor's AVE is more than the co-relation coefficient when compared with other factors, indicating the discriminant validity criterion is supported for the measurement model (Fornell and Larcker 1981).

Table 5. Discriminant validity

For exploring the new technical skill requirement not covered in the existing competence framework, a section of questionnaire was dedicated to open-ended questions such as 'What technical competence or skills do you think would be important for future navigators?' The respondents were asked to describe in few sentences of their opinion regarding which skills would be needed and reasons for the same. The qualitative responses were then analysed through

Table 4. Reflexive indicator loadings, CR and AVE of the measurement model.

No.	Competence theme	Indicators	Loading	CR	AVE
1	Position fixing & Watchkeeping	KUP 3	.733	.853	.498
		KUP 2	.591		
		KUP 1	.508		
		KUP 6	.831		
		KUP 15	.785		
		KUP 7	.733		
2	Inspect and report defects and damages to cargo spaces, hatch covers & ballast tanks	KUP 40	.841	.894	.627
		KUP 39	.747		
		KUP 41	.800		
		KUP 42	.821		
		KUP 38	.746		
3	Prevent, control and fight fires onboard	KUP 52	.884	.908	.712
		KUP 54	.869		
		KUP 53	.860		
		KUP 51	.757		
4	Contribute to safety of personnel and ship	KUP 63	.718	.890	.670
		KUP 65	.865		
		KUP 64	.874		
		KUP 66	.807		
5	Use of radar, ARPA and ECDIS to maintain safety of navigation	KUP 24	.820	.881	.649
		KUP 22	.828		
		KUP 23	.819		
		KUP 25	.753		
6	Application of leadership and teamworking skills	KUP 61	.869	.879	.647
		KUP 60	.844		
		KUP 58	.762		
		KUP 62	.733		
7	Ensure compliance with pollution prevention	KUP 46	.907	.925	.805
		KUP 45	.913		
		KUP 44	.870		
8	Damage control and distress communication	KUP 28	.852	.864	.679
		KUP 27	.793		
		KUP 29	.826		
9	Application of meteorological information in navigation	KUP 11	.878	.863	.678
		KUP 10	.816		
		KUP 9	.773		
10	Reporting and communication	KUP 31	.887	.842	.728
		KUP 17	.818		
11	Manoeuvring and maintaining seaworthiness of ship	KUP 33	.927	.828	.709
		KUP 47	.749		

iterative thematic coding. Any overlap with existing technical skills or competence themes was discarded and only the unique themes emerging were retained in the analysis. These emerging themes were labelled as the ‘additional technical skills’ the future navigators will require in addition to the already existing ones as listed in the STCW framework.

In the obtained qualitative responses provided by the respondents, the results indicated that the increasing automation would mean that the future seafarers or navigators should be well versed with relevant IT skills that could facilitate the operations onboard. The respondents described that the elementary knowledge regarding coding, and comprehension of machine learning algorithms will be necessary for the future navigators due to the presence of numerous intelligent decision support systems. The respondents also added that due to further advancement towards engine room automation, it might be the case that the crew compliment onboard is further reduced, and the navigators are also trained for engine room operations or for a basic knowledge thereof contributing to the development of a new hybrid role with equal competence requirement for both navigation and engine operations. Due to potential introduction of complex electronic equipment, a separate competence theme addressing the elementary fault finding and troubleshooting aspects will be necessary to ensure smooth functioning of major operational equipment onboard.

Further, the advent of integrated systems on ships will mean that the navigators or the remote-control operators are well versed with knowledge regarding instrumentation & control and operation of diverse types of sensors as well as their limitations. Lastly, the importance of managing risks when abnormal situation arises due to failure/deviance of system and expertise in cyber security will be paramount in day-to-day operations for autonomous ships.

In summary, five major novel technical competence themes emerged during the thematic analysis, namely—*IT skills, safety & security management skills, knowledge regarding engine room operations, electronic equipment and system integration*. The new technical competence themes are highlighted using the thematic map as illustrated in Figure 3.

4.2. Part-B

The second part of the survey recorded the data regarding the relative importance of listed cognitive and social skills in the reviewed literature under Degree 2 MASS operations. With respect to the non-technical skills, there were relatively few measurement items and each of them received identical scores. Therefore, along with the scores, a measure of proportion was employed to identify which skills are relatively important among the listed. With regards to the cognitive skills, *the ability to maintain adequate situational awareness* obtained the score of 1.90 (most important) also with a proportion of 34.2% which was the highest proportion for *extremely important* category. For the purpose of visualization of this data, Figure 4 illustrates the summative evaluation of 109 responses on each of the cognitive skills.

For social skills, *the ability to take leadership initiatives* received a score of 1.95 and the highest proportion of respondents marking it as *extremely important*—37.5%. Majority of the respondents termed the required social skills as either 'Very important' or 'Extremely important'. This was also found to be the case for aforementioned cognitive skills. For the purpose of visualization of this data, Figure 5 illustrates the summative evaluation of 109 responses on each of the social skills.

For the non-technical skills, an exploratory question—*What non-technical competence or skills do you think would be important for future navigators?* was included in the survey questionnaire to identify competence themes in addition to the ones contained in the questionnaire. As a result, five major themes emerged with regard to cognitive skills namely—*non-routine problem solving, ability*

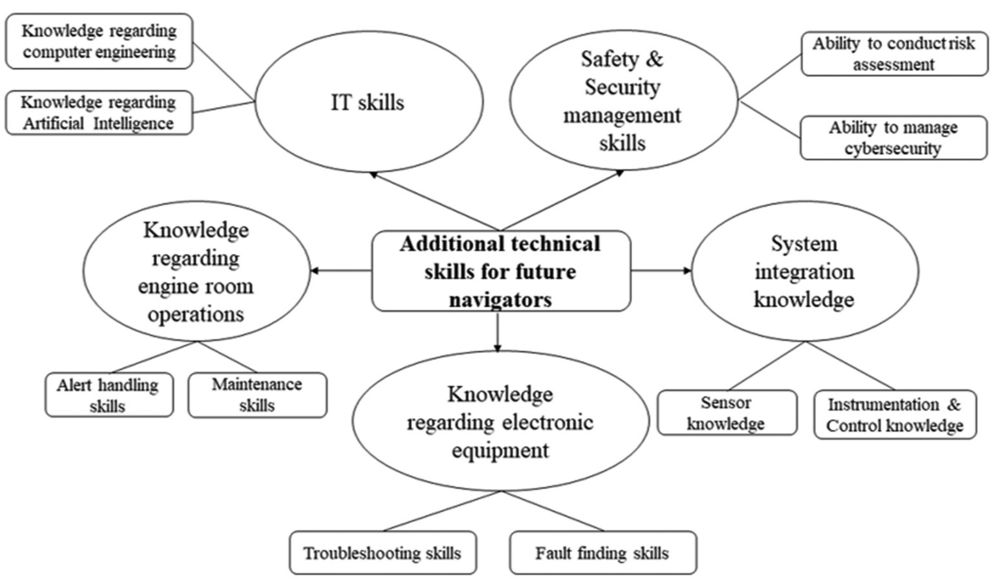

Figure 3. Additional technical skill relevant for autonomous operations.

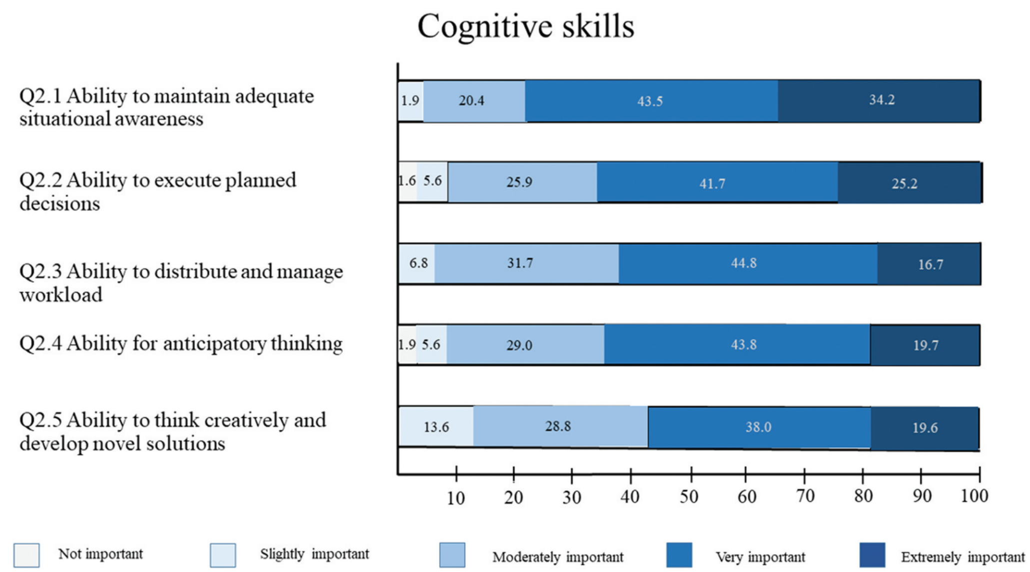

Figure 4. Descriptive statistics for cognitive skills.

for self-regulation, critical thinking, mental readiness and systemic thinking. Similarly, for social skills, three major themes such as—*ability to establish trust in teams, ability to adapt to cultural differences and negotiation skills* emerged. These emerged themes were labelled as 'additional non-technical skills' for the navigators. The respondents claimed that the due to increased automation and possible reduction to bare-minimum crew members, considerable emphasis to cultivation of non-technical skills is required. This could entail a relatively small team of seafarers onboard or one remote control center tackling many operations related to ship.

In this regard, skills such as self-regulation, critical thinking and non-routine problem solving are particularly important as indicated by the respondents. Further, it was described by the

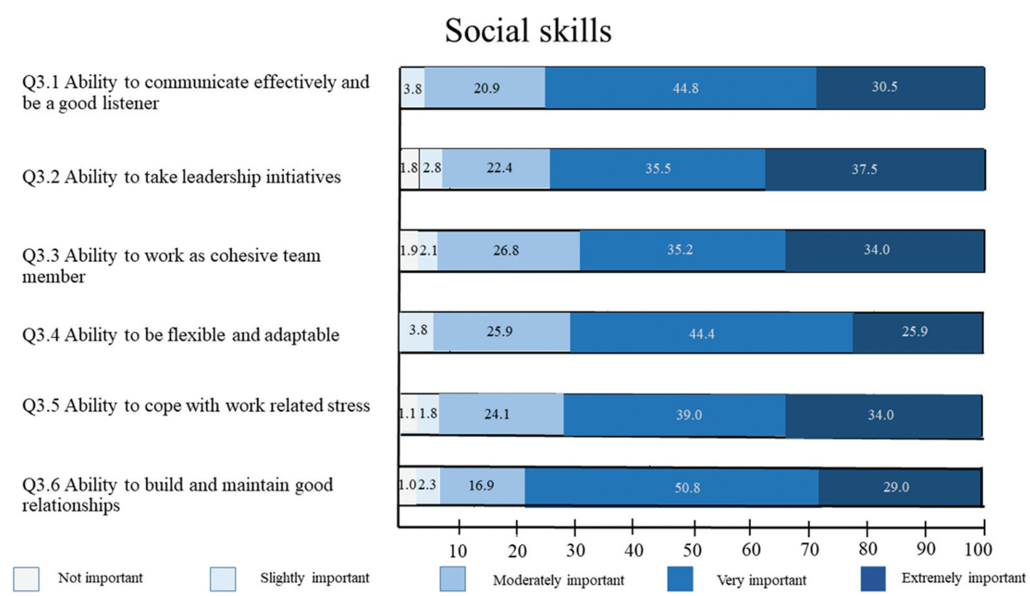

Figure 5. Descriptive statistics for social skills.

respondents that due to unanticipated situations arising due to hidden properties and interaction between various components within the system, navigators of the future will need to demonstrate considerable mental readiness for handling complex situations and systemic thinking skills. With regards to the existing international nature of shipping industry, characteristics such as ability to earn trust, negotiation and awareness regarding cultural difference between individuals were termed as some of the important social skills to possess. The newly emerged non-technical competence themes are highlighted in a thematic map as illustrated in Figure 6.

5. Discussion

The existing shipping regulations need to be revised or updated in light of the developments taking place with respect to autonomous shipping globally, otherwise they may form a self-limiting regulatory barrier for introduction and adoption of autonomous shipping. The present study intended to target these aspects of autonomous shipping and facilitate improved understanding of regulatory changes that may be required.

The results derived from analysis provided an insight towards competence requirements for Degree 2 MASS operations and suitability of existing STCW competence framework. As illustrated in the EFA results (Part A), some of the original competence themes were still deemed necessary in the era of autonomous shipping. This to a certain extent is expected as Degree 2 MASS operations, though represents further advancement in ship operations and many shipboard functions, still doesn't amount to 'crew-less' operations. Degree 2 MASS operations, is the next step in the continuum of autonomy leading to completely autonomous ships. Consistent with the definition of Degree 2 MASS operations, the seafarers, are still present onboard to take control if necessary (IMO 2018). However, their roles and as a result, the competence requirement are indicated as more towards supervisory functions and emergency response. This is indicated by the fact that the individual items such as KUP 26 *Ability to take precautions for the protection and safety of passengers in emergency situations* and KUP 27 *Ability to take initial actions following a collision or a grounding*; received the lowest score (most important)—1.48 and 1.51, respectively, in the survey. Some new competence themes as a result of covariance in relevant KUPs also occurred. Emergent competence themes such as—*Position fixing & watchkeeping* and *Damage control and distress communication* among others provide such examples. Several competence themes such as—*Application of leadership & teamworking skills* and *Ensure compliance with pollution prevention* remain relevant. Correspondingly, a modified set of KUPs will be needed to be established in the future for adequately addressing training requirements for different levels of autonomous operations.

The emergent competence themes as derived in Table 3 along with the novel competence themes as illustrated in Figure 3 together address the technical skills as required from future seafarers engaged in Degree 2 MASS operations. There is a marked trend with shift of emphasis from navigational functions that are projected to be automated with time, towards other aspects of ship operations. In this regard, Wróbel, Montewka, and Kujala (2017) had also remarked that with increase in automation onboard, navigational risks such as collision and grounding might decrease and non-navigational risks such as fire, flooding etc will increase. The increased automation and digitalization onboard vessels will introduce vulnerabilities in addition to mere safety. It has increasingly been recognized that merchant ships are becoming susceptible for cyber-attacks. Jones, Tam, and Papadaki (2016) provided scenarios and pointed out the potential weaknesses of various bridge equipment such as ECDIS, GPS, AIS etc. In this regard, the presence of human crew onboard becomes the first line of defence, training and instilling skills for detecting and responding to cyber-attack is relevant for future autonomous operations.

A considerable number of respondents also stressed the importance of acquisition of non-technical skills for autonomous operations. According to Ahvenjärvi (2016), the obvious strength of human element in these complex systems onboard will be their flexibility and creativity.

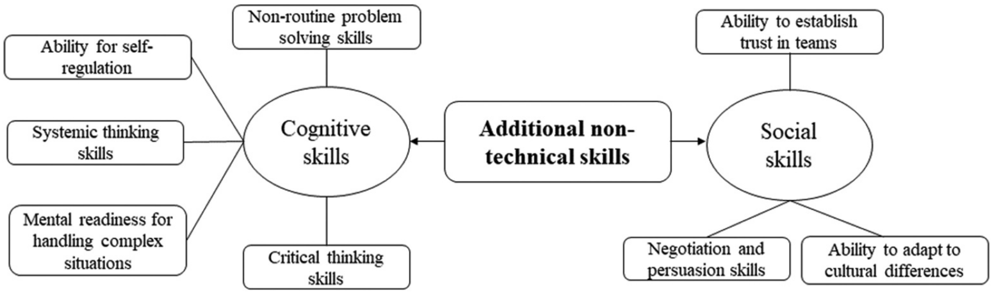

Figure 6. Additional non-technical skills relevant for autonomous operations.

Therefore, adequate exploration regarding non-technical skills in maritime operations and training measures to support them need to be recognized. The qualitative data has indicated that future navigators should engage in systemic thinking competence. This is somehow anticipated as the future systems with deployment of Artificial Intelligence (AI) and automation technologies would mean that the systems will become more and more complex with increasing invisible interactions. It is paramount for the crews onboard to be able to have a holistic and systemic understanding of the systems and its interactions, to be able to comprehend the complexity, to evaluate the interrelations of sub-systems and to subsequently generate the best decisions and course of actions. Furthermore, effective leadership, which is an important element for safe operation today will play an increasingly important role in the autonomous era in order to effectively handle the ship in both normal and abnormal situations. Good leadership correlates with good safety performance, the decisions, attitudes and behaviours of leaders at all organizational levels shape the safety culture and working environment which determines the end results (Flin and Yule 2004; Kim and Gausdal 2017). In the era of autonomous shipping where information flow will determine the decisions and directions, in which ways shipping company and its management could effectively take advantage of the automation technology for safe, reliable and efficient ship operations is a topic worthy of further investigation.

Several limitations of the present research need to be mentioned. First of all, the sample size can be increased to enhance validity and generalizability of the results. Further, challenges with respect to subjectivity can be listed even after rigorous data analysis process conducted, since both labelling the extracted factors during EFA process as well as labelling of competence themes from thematic analysis are subjective in nature. These limitations mean that the results derived should be considered preliminary and further exploration with greater sample size is needed. Future research should be directed in examining the suitability of other competence requirements stipulated in STCW (e.g., Table A-II/2) as well as for roles within other departments in merchant shipping sector such as marine engineer officers. Such investigation carried out by different stakeholders could aid the revision and integration of changes that will be required for the STCW Convention and its associated Code to prepare competent seafarers for the dynamically evolving nature of autonomous shipping.

6. Conclusion and policy implications

Implementation of autonomous shipping technologies has the potential for enhancing safety, efficiency and sustainability performance of maritime industry. However, the regulatory framework for autonomous operations and the investigation for role of human element is in its initial stages. Modelling competences and anticipating the future competence for navigators or operators under plausible autonomous shipping scenarios could be the first stage in preparing for the challenges and opportunities autonomous shipping offers.

Through quantitative and qualitative analysis of a representative sample from the global shipping industry, the suitability of existing STCW competence requirements as well as the new competence themes that will be required under manned and remotely controlled MASS operations were presented in this research. Among the original 66 KUP items, 26 of them were rated by the respondents to be considered as less relevant for future navigators. The 11 competence themes emerged through the statistical analysis, together with the social and cognitive skills derived from the thematic analysis, can be considered as the reference for reskilling of future navigators. The results may contribute to the existing discussions regarding the revision of the STCW convention and its associated codes, in particular the STCW Table A-II/1 to facilitate the preparation and implementation of novel training frameworks for autonomous shipping. The research could aid the curriculum design in MET institutions to equip the trainees with updated skillset for safe and efficient operations. Future research should be directed at investigating the competence requirements for various roles involved in MASS operations.

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Article 2

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education sciences

Article

Assessing the Technology Self-Efficacy of Maritime Instructors: An Explorative Study

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Abstract: Maritime Education and Training (MET) is an integral part of the global maritime industry, playing an essential role in ensuring that the sector is supplied continuously with a skilled workforce. The successful outcomes of the educational content delivery in MET institutes depend, to a certain extent, on the maritime instructor's ability to create conducive learning environments utilizing all of the resources available. The self-efficacy of maritime instructors in various facets, most notably their proficiency with the use of technology in classrooms, can lead to the introduction of transformative learning practices. Accurately measuring their self-reported technological proficiency could be the initial step in this direction. This study aimed to measure the self-reported technology proficiency of maritime instructors using an established and validated scale: Technology Proficiency Self-Assessment for the 21st century (TPSA-C21). The scale was administered, using an online survey, to a sample of MET instructors within Europe and the UK, with n = 62 valid responses received. Using descriptive statistics and the evaluation of the measurement model, the study highlighted the perceived level of proficiency of the MET instructors along dimensions such as email, world-wide web use, emerging tools, teaching with technology, integrated applications, and teaching with emerging technologies. The survey also measured the perceived level of technology integration for maritime instructors according to the Concerned-Based Adoption Model–Level of Use (CBAM–LoU) classification. The results indicate a potential area of improvement for maritime instructors with regard to their self-reported proficiency, namely in the dimension of teaching with emerging technology. The implications for the MET domain, the respondent demographics and the future research directions are discussed.

Keywords: maritime education and training; maritime pedagogy; TPSA-C21; self-efficacy

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1. Introduction

Maritime Education and Training has been referred to as one of the six pillars of the global maritime industry by the International Maritime Organization [1]. The maritime industry plays an indispensable role in the global economy, and enables trade and the movement of goods and services across various continents. The European region has historically been recognized as influential in the maritime industry due to the presence of key maritime clusters in the region, which have traditionally facilitated knowledge exchange, collaboration, research, and the development of maritime technology [2]. About 43,000 ships ply the European waters alone; they are instrumental in the transport of valuable goods and passengers, and in the value creation and sustainable solutions in the supply chain of the region [3]. The availability of technical capital in the region has also been simultaneously linked with the presence of human capital itself, with maritime professionals and seafarers providing the knowledge and experience for the operations. The availability of this relevant human capital is supported by the well-established Maritime Education and Training (MET) institutes in the region. There are numerous MET universities and vocational MET institutes in Europe (and the UK) [4], providing various courses and programs for competence development, the fulfilment of the regulatory requirements, and research and development in the maritime sector.

The operational environment related to the maritime domain has evolved steadily over the years. From isolated floating workspaces with labour-intensive working arenas, ships have transformed into valuable assets which are linked using Information and Communication Technologies (ICTs) to the larger supply chain involved in the movement of goods [5]. Many modern ship operations are managed or assisted via shore offices at present. A parallel trend has been replacement of many functions onboard with automation, with crew members primarily supervising the performance of the automation agents. Correspondingly, the crew size has shown a trend of reduction, along with a change in their skillsets and competence requirements. Many researchers have addressed these developments, with commentary on the need for ICT skills training for contemporary seafarers [6,7] along with the need to balance the academic aspects of MET with the predominant vocational aspects [8].

The technological innovations of the 21st century are leading us towards changes in the dynamics of education and its delivery globally. The advancements in Information and Communication Technologies (ICTs) have resulted in the availability of educational solutions that enable the ubiquitous delivery of content and novel opportunities for communication and collaboration when engaging with that content. The maritime domain has also adopted modern ICTs and developments in the learning sciences through the use of distance learning, simulator-based learning, e-learning and other initiatives [9,10]. Some other emerging trends that hold substantial potential for Maritime Education and Training are Artificial Intelligence and Virtual/Augmented Reality [7,11]. However, the utilization of any technology or its integration into classrooms, to a certain extent, depends upon the teachers and instructors, who are typically responsible for achieving the learning objectives set out in the educational programs [12]. Even though we have seen a considerable increase in the use of distributed learning solutions in recent years, traditional hierarchical learning solutions—in which the training and education are facilitated in an established institution and mediated by instructors—are still relevant for a majority of maritime operations.

Technology integration in the classroom can be generally defined as the use of technological resources such as personal computers, laptops, smart phones, tablets, and other devices with or without internet support for carrying out activities related to the learning and assessment. Davies and West [13] (p. 843) gave a more formal definition as “the effective implementation of educational technology to accomplish learning outcomes”. Educational technology itself can be any tool or device, whether electronic or mechanical, that can be used for achieving the intended learning goals. In the learning sciences, various models of technology integration for classrooms have been proposed over the past several years [14]. The models for technology integration can further be divided into the models that focus on the removal of barriers that hinder the use of ICTs in the classrooms [15] and the models that focus on the personal skill set of the instructors and their proficiency with the ICTs [16].

The arguments in support of technology integration are numerous, the most prominent being the need for the cultivation of 21st century skills, such as communication, collaboration, critical thinking and creativity, etc. [17,18]. The possession of such a skillset is thought to be a requirement for a generic worker in any socio-technical system, including the maritime domain [19], in which human and automation agents work in tandem with close and continuous collaboration. As Artificial Intelligence and Digitalization make further inroads in the maritime domain, it will require a reimagination of the operational processes, with the automation agents taking over most of the redundant and repetitive tasks, whereas the human operators are expected to be able to augment their creative and reasoning abilities to enhance the system performance and ensure safe outcomes [11]. Such a change, although gradual, can be expected to take place in the coming years. It would require an appropriate response from the researchers and practitioners associated with the MET community to ensure that the seafarers are ready to face technological challenges through the possession of appropriate skills and competencies. In addition, the current pandemic of COVID-19 has also put constraints on the infrastructure of MET institutes. The pandemic has necessitated the adoption of measures to ensure that remote and e-learning measures are in place to continue the training and assessment of maritime trainees. Here, the maritime instructors, who are responsible for the education of future seafarers, play a crucial role. The maritime instructors who are responsible for instilling the required competencies to the maritime trainees use various instructional tools and resources to ensure the satisfactory transfer of knowledge in the classrooms and simulators [20,21]. The ongoing changes in the learning environment related to the use of a variety of digital affordances and existing infrastructure put the focus on the resources made available to the maritime instructors and their self-perceived efficacy in their use.

In light of above, the primary research objective for this study is to assess the technology self-efficacy of the maritime instructors. Utilizing a validated scale to measure the self-reported technological proficiency of the maritime instructors could aid in mapping and identifying areas of possible improvement. In this paper, we utilize the Technology Proficiency Self-Assessment for the 21st Century (TPSA-C21) questionnaire for the measurement of the self-reported technological proficiency of maritime instructors from a selection of MET institutes in Europe and the UK. In the subsequent sections, first, a brief review of the associated terms and literature is carried out. The context of the present study is also elaborated upon. Furthermore, the methods for conducting the data collection and analysis are described. This is followed by a description of the obtained research results from the study and discussions highlighting the contribution, limitations and potential areas of future research.

2. Context and Literature Review

The maritime industry depends on certain factors to ensure safe outcomes in day-to-day operations, with one of them being a qualified and skilled workforce. The elemental function of the maritime industry is to transport goods and services across the globe. It employs high value assets, i.e., ships, towards this end, which are manned by seafarers. The International Maritime Organization (IMO), through the Standards of Training, Certification and Watchkeeping (STCW) regulations, aim to ensure standardization in seafarer's qualifications for all of the signatory member states. According to the European Maritime Safety Agency, about 210,000 masters and officers are working on ships that possess a valid Certificate of Competency (CoC) issued by an EU member state [22]. In order to possess a valid CoC and other mandatory certificates following the provisions of the STCW, the seafarers have to undergo various stipulated courses in an approved Maritime Education and Training (MET) institute. MET institutes, therefore, make an important contribution towards ensuring the supply of a skilled workforce for the maritime industry. As there has been a steady demand for skilled and qualified seafarers for the maritime industry over the decades [23], and given the fact that many of these certifications often also require periodic renewals, the MET institutes have a dynamic and evolving role to perform. The STCW regulations have been revised in the past to keep up with the changing workplace environment and, as a consequence, competence requirements within the maritime industry [11]. This has been the case with MET institutes and the modes of educational content delivery [24]. The MET institutes not only need to possess adequate infrastructure to utilize various modes of educational content delivery; there is also a need for the maritime instructors to continuously update their pedagogical profile and explore the use of digital technologies. STCW regulation I/6 stipulates that the person responsible for conducting courses that lead up to the issuance of a certificate for a seafarer should also be adequately qualified. As a response, the IMO came up with Model Course 6.09 "Train the Trainer" and 6.10 "Train the simulator trainer and assessor", which, amongst other things, focus on the role of instructor, the learning process, the design of the training program, and the use of teaching aids. The development of a pedagogical profile and continuous professional development of maritime instructors are therefore deemed important for the maritime industry. The instructors should feel sufficiently confident in their own ability to utilize the technological tools available to them to impart lessons pertaining to the courses.

Technology integration has received increasing attention in the studies related to educational sciences in recent years. This can be partly ascribed to the increasing availability of digital tools in educational content design and delivery [25]. Whereas the use of any technological tool does not guarantee the better transfer of training, it does transform the nature of the educational delivery [26]. Some of the ICT tools can increase the instructor's outreach and improve their efficiency if utilized properly. Instructors engaged in vocational education and training are increasingly adopting novel modes of educational content delivery to improve the learning outcomes for the educational programs [27,28]. Various studies have pointed to the fact that the use of technological tools by the instructors in the classrooms depends on their self-efficacy towards them [29,30]. Self-efficacy, in simple terms, can be defined as the belief of an individual that the task he or she is performing will lead to the desired outcomes. Self-efficacy as a concept has underpinnings in Social Cognitive Theory [31]. Bandura [32] stated that self-efficacy could be a good predictor of a behavior. It is also termed as one of the factors that influences the effectiveness of the teaching [33].

Measuring and improving self-efficacy in the use of technological tools for the instructors can therefore help in their capacity development. In this regard, Christensen and Knezeck [34] argue that the ability to integrate 21st century technology for learning and proficiency in the use of these technologies has a vital role in modern educational institutions. They proposed a validated instrument known as the Technology Proficiency Self-Assessment for the 21st Century (TPSA-C21) for the measurement of self-reported self-efficacy scores for the instructors, with reference to the prominent technological tools adopted in the contemporary classrooms. The theoretical underpinnings of the scale were discussed by Christensen and Knezeck (p. 312, [35]); they stated that it is grounded in the concept of "Self-efficacy", which they defined as "confidence in one's competence". The scale was adapted from the earlier version of the instrument, known as the Technology Proficiency Self-Assessment (TPSA), which was developed by Ropp [36]. It has previously been used by [37] to measure confidence in integrating technology into classrooms in the USA, and by [38] as a measure which was further correlated with the age, gender and subject area of the respondents. The original TPSA scale measured technology proficiency in four dimensions, i.e., using electronic mail (Email), using the world wide web (WWW), using technology applications, and proficiency in teaching with technology [39]. After reviewing the performance of the scale and taking into account the recent developments, two more dimensions of technological proficiency, namely emerging tools and teaching with emerging technologies, were included in the scale by Christensen and Knezeck [34]. The six sub scales, along with their definitions, are described below:

- Email: the ability to send a document as an attachment to an email message.
- WWW: the ability to find the primary resources of information on the internet that can be used in teaching.
- Emerging tools: the ability to save and retrieve files from a cloud-based environment.
- Teaching with technology: the ability to use technology to collaborate with teachers or students who are distant from the classroom.
- Integrated applications: the ability to use a spreadsheet to create a bar graph of the proportions of different colours.
- Teaching with emerging technologies: the ability to teach in a one-to-one environment in which the students have their own devices.

These six sub-scales, taken together, aim to provide a measure of the technology proficiency of the instructors. The instrument can also be used to compare groups of instructors, or to carry out a longitudinal study on the same group of instructors to measure any change due to training interventions. Accurately measuring the technology self-efficacy of the MET instructors can be the first step in identifying their training requirements and the need for policy interventions, if any. To the best of our knowledge, the quantitative assessment of self-reported technology proficiency or technology self-efficacy for maritime instructors in the European context has not been attempted in the existing research literature related to MET. In the next section, we elaborate upon the steps followed to achieve this aim.

3. Methods

In order to achieve the research objective, the TPSA-C21 questionnaire was digitalized in the platform Nettskjema®, a Norwegian secure service solution for data collection which supports the drafting process of online survey links. There are a total of 34 questions in the TPSA-C21 questionnaire, which together provide the scores related to the 6 sub-scales. Their grouping is as follows: Email (Q.1–5), WWW (Q.6–10), Integrated Applications (Q.11–15), Teaching with technology (Q.16–20), Teaching with emerging technologies (Q.21–28) and Emerging tools (Q.29–34). The online link of the questionnaire was distributed to the professional contacts, who were MET instructors within a European MET (additionally in the UK) institute using an email platform. The scope of the study was limited to Europe and the UK in order to ensure the sufficient generalizability of the research outcomes. The respondents were asked to rate each item from "Strongly Disagree" to "Strongly Agree" and anything in between Likert scale numbering 1 to 5. A few demographics questions, such as Gender, Age, Years of experience, and Country of origin were also inserted at the beginning in order to facilitate the understanding of the obtained data. Furthermore, towards the end of the questionnaire, the respondents were also asked to rate their level of technology proficiency using the Level of Use scale [40]. This is a self-assessment instrument based on the Concern Based Adoption Model (CBAM), and it lists 8 levels of educational innovation: (1) Non-use, (2) Orientation, (3) Preparation, (4) Mechanical use, (5) Routine, (6) Refinement, (7) Integration, and (8) Renewal [41]. All of the ethical guidelines of the affiliated institution regarding anonymity and data collection were followed. The ethical permission to collect and process the data was obtained from the Norwegian Centre for Research Data (NSD) via a notification form, reference number 471618, in March 2020.

The method of data collection was a non-random, purposive sampling approach through the professional networks of MET universities. The data collection stage lasted from May 2020 to November 2020. At the end of this period, a total number of 76 responses were obtained. The data was then checked for anomalies, and 14 responses were removed due to either being incomplete or straight-lining the responses. Finally, a total number of n = 62 valid responses were extracted which were deemed fit for further analysis. The data was then analyzed for descriptive statistics and measurement model assessment using Microsoft Excel®, and the statistical software packages SPSS® and SmartPLS3®. The calculation of the descriptive statistics and the non-parametric statistical test, for the examination of the differences in means by groups such as educational qualifications and years of experience using the Kruskal–Wallis test was conducted through SPSS®. For the measurement model assessment through Confirmatory Composite Analysis (CCA), SmartPLS3® was utilized, along with the guidelines given by Hair et al. [42,43]. Accordingly, the factor loadings for items under each dimension, Composite Reliability, Cronbach's Alpha, Rho Alpha, Average Variance Extracted and Heterotrait–Monotrait ratios were obtained. For the non-parametric Kruskal–Wallis test, Chi-square and P significance values were obtained for the comparison. The average age of the respondent was 43.0 years (SD = 5.46 years). The rest of the demographic data is summarized in Table 1. Most of the respondents stated their country of origin as Norway (29%), followed by Sweden (17.7%), Denmark (12.9%), the UK (9.7%), Germany (6.4%), Belgium (4.8%), and the Netherlands (1.6%). The rest (17.9%) did not specify their country of origin. The obtained scores and values for various statistics for the TPSA-C21 sub-scales and each item under them are described in detail and discussed in the next section.

Table 1. Demographic characteristics of the respondents.

Demographic		Frequency	Percent
Gender	Male	52	83.9
	Female	10	16.1
Educational Qualifications	Bachelors	10	16.1
	Masters	36	58.0
	Doctorate	13	21.0
	Other	3	4.9
Years of experience	0–5 years	17	27.4
	6–10	14	22.6
	11–15	10	16.1
	+15 years	21	33.9

4. Results

The TPSA-C21 scores for each of the subscales are elaborated below.

4.1. Email

The Email subscale consisted of five items. Their individual scores, factor loading, reliability value and Kruskal–Wallis test results are given below (Table 2).

Table 2. Self-reported proficiency of maritime instructors along the dimension 'Email'.

Q.No.	Mean	SD	Factor Loading	Qualifications Chi.sq/Sig.	Experience Chi.sq/Sig.
Q.1—Send an email to friend	4.74	0.57	0.767	7.055/0.070	1.667/0.664
Q.2—Subscribe to a discussion list	4.68	0.59	0.896	7.058/0.070	1.923/0.589
Q.3—Create a distribution list to send email to several people at once	4.60	0.69	0.759	12.990/0.005 *	2.380/0.497
Q.4—Send a document as an attachment to an email	4.81	0.47	0.860	11.982/0.007 *	4.286/0.232
Q.5—Keep copies of outgoing message that I send to others	4.73	0.55	0.841	16.226/0.001 *	4.260/0.235

Note: SD = standard deviation; Chi.sq = chi square; Sig = significance; * = significant at the $p < 0.01$ level.

4.2. World Wide Web

The World Wide Web subscale consisted of five items. Their individual scores, factor loading, reliability values and Kruskal–Wallis test results are given below (Table 3).

Table 3. Self-reported proficiency of maritime instructors along the dimension 'World Wide Web'.

Q.No.	Mean	SD	Factor Loading	Qualifications Chi.sq/Sig.	Experience Chi.sq/Sig.
Q.6—Use internet search engine to find Web pages related to my subject matter interests	4.85	0.40	0.713	10.146/0.017	1.614/0.656
Q.7—Search for and find Smithsonian institute website	4.60	0.84	0.852	9.017/0.029	4.895/0.180
Q.8—Create my own webpage	3.37	1.26	0.464	0.990/0.804	1.461/0.691
Q.9—Keep track of websites I have visited so that I can return to them later	4.56	0.82	0.865	10.534/0.015	2.505/0.474
Q.10—Find primary sources of information on the internet that I can use in my teaching	4.65	0.66	0.854	14.630/0.002 *	3.402/0.334

Note: SD = standard deviation; Chi.sq = chi square; Sig = significance; * = significant at the $p < 0.01$ level.

4.3. Integrated Applications

The Integrated applications subscale consisted of five items. Their individual scores, factor loading, reliability value and Kruskal–Wallis test results are given below (Table 4).

Table 4. Self-reported proficiency of maritime instructors along the dimension 'Integrated Applications'.

Q.No.	Mean	SD	Factor Loading	Qualifications Chi.sq/Sig.	Experience Chi.sq/Sig.
Q.11—Use spreadsheets to create a bar graph of the proportions of different colours	4.26	1.02	0.879	8.805/0.032	2.817/0.421
Q.12—Create a newsletter with graphics	4.00	1.19	0.811	5.723/0.126	1.589/0.662
Q.13—Save documents in formats so that others can read them if they have different word processing programs	4.60	0.80	0.884	14.141/0.003 *	1.537/0.674
Q.14—Use the computer to create a slideshow presentation	4.81	0.47	0.802	20.729/0.000 *	3.116/0.374
Q.15—Create a database of information about important authors in a subject matter field	4.08	1.03	0.726	8.361/0.039	1.112/0.774

Note: SD = standard deviation; Chi.sq = chi square; Sig = significance; * = significant at the $p < 0.01$ level.

4.4. Teaching with Technology

The Teaching with technology subscale consisted of five items. Their individual scores, factor loading, reliability value and Kruskal–Wallis test results are given below (Table 5).

Table 5. Self-reported proficiency of maritime instructors along the dimension 'Teaching with technology'.

Q.No.	Mean	SD	Factor Loading	Qualifications Chi.sq/Sig.	Experience Chi.sq/Sig.
Q.16—Write an essay describing how I would use technology in my classroom	4.45	0.84	0.770	9.109/0.028	4.277/0.233
Q.17—Create a lesson or unit that incorporates subject matter software as an integral part	4.06	0.97	0.855	9.122/0.028	3.519/0.318
Q.18—Use technology to collaborate with teachers or students, who are distant from my classroom	4.53	0.72	0.850	11.822/0.008 *	3.415/0.332
Q.19—Describe 5 software programs or apps that I would use in my teaching	4.03	1.09	0.732	13.021/0.005 *	3.225/0.358
Q.20—Write a plan with a budget to buy technology for my classroom	4.10	1.02	0.777	14.592/0.002 *	1.208/0.751

Note: SD = standard deviation; Chi.sq = chi square; Sig = significance; * = significant at the $p < 0.01$ level.

4.5. Teaching with Emerging Technology

The Teaching with emerging technologies subscales consisted of eight items. Their individual scores, factor loading, reliability value and Kruskal–Wallis test results are given below (Table 6).

4.6. Emerging Tools

The Emerging tools subscale consisted of six items. Their individual scores, factor loading, reliability value and Kruskal–Wallis test results are given below (Table 7).

Table 6. Self-reported proficiency along the dimension 'Teaching with emerging technology'.

Q.No.	Mean	SD	Factor Loading	Qualifications Chi.sq/Sig.	Experience Chi.sq/Sig.
Q.21—Integrate mobile technologies into my curriculum	4.11	0.96	0.823	7.065/0.070	1.146/0.766
Q.22—Use social media tools for instruction in the classroom	3.47	1.46	0.616	7.046/0.070	0.672/0.880
Q.23—Create a wiki or blog to have my students collaborate	3.47	1.22	0.706	5.104/0.164	2.649/0.449
Q.24—Use online tools to teach my students from a distance	4.48	0.80	0.814	3.925/0.270	1.490/0.685
Q.25—Teach in one to one environment in which students have their own device	4.44	0.74	0.714	4.314/0.229	4.170/0.244
Q.26—Find a way to use smartphone in my classroom for student responses	4.15	1.02	0.883	6.732/0.081	2.596/0.458
Q.27—Use mobile devices to connect with others for my professional development	4.13	1.00	0.846	3.162/0.367	3.981/0.263
Q.28—Use mobile devices to have my students access to learning activities	4.18	0.97	0.885	4.831/0.185	3.859/0.277

Note: SD = standard deviation; Chi.sq = chi square; Sig = significance; * = significant at the $p < 0.01$ level.

Table 7. Self-reported proficiency of maritime instructors along the dimension 'Emerging tools'.

Q.No.	Mean	SD	Factor Loading	Qualifications Chi.sq/Sig.	Experience Chi.sq/Sig.
Q.29—Download and listen to podcasts/audiobooks	4.42	0.80	0.885	10.011/0.018	2.386/0.496
Q.30—Download and read e-books	4.48	0.78	0.915	13.894/0.003 *	2.626/0.453
Q.31—Download and view streaming movies/videoclips	4.56	0.74	0.908	6.441/0.092	4.754/0.191
Q.32—Send and receive text messages	4.74	0.48	0.573	9.311/0.025	4.702/0.195
Q.33—Transfer photos or other data via a smartphone	4.76	0.62	0.892	7.505/0.057	2.031/0.566
Q.34—Save and retrieve files in a cloud based environment	4.58	0.74	0.876	7.308/0.063	1.230/0.746

Note: SD = standard deviation; Chi.sq = chi square; Sig = significance; * = significant at the $p < 0.01$ level.

Table 8, below, represents the Cronbach's Alpha (CA), Composite Reliability (CR), Rho Alpha and Average Variance Extracted (AVE) values. The first three measures denote the dimensions' construct validities, while AVE denotes the convergent validity.

Table 8. Cronbach's Alpha (CA), Composite Reliability (CR), Average Variance Extracted and Rho_Alpha.

Dimension	CA	CR	Rho-Alpha	AVE
Email	0.883	0.915	0.895	0.683
WWW	0.814	0.871	0.865	0.585
Integrated Applications (IA)	0.879	0.912	0.890	0.677
Teaching with technology (TWT)	0.857	0.897	0.863	0.637
Teaching with emerging technology (TWET)	0.912	0.930	0.927	0.626
Emerging tools (ET)	0.920	0.939	0.949	0.723

Table 9, below, describes the Heterotrait–Monotrait ratio values as a measure of the dimension's discriminant validity.

Table 9. Heterotrait–Monotrait Ratio (HTMT) values of the dimensions.

Dimension	Email	WWW	IA	TWT	TWET	ET
Email	-	-	-	-	-	-
WWW	0.913	-	-	-	-	-
Integrated Applications	0.745	0.928	-	-	-	-
Teaching with technology	0.738	0.871	0.986	-	-	-
Teaching with emr. technology	0.463	0.542	0.765	0.840	-	-
Emerging tools	0.730	0.595	0.820	0.802	0.784	-

Table 10, below, describes the frequency and percentage distribution of the maritime instructors, marking them as belonging to one of the levels (0–6) of the CBAM-LoU classification in their ability to integrate technology for their own use.

Table 10. Concern-Based Adoption Model–Level of Use (CBAM–LoU) frequency distribution.

Level of Use	Frequency	Percent	C. Percent
Level 0—Non use	-	-	-
Level 1—Orientation	-	-	-
Level 2—Preparation	2	3.2	3.2
Level 3—Mechanical use	15	24.2	27.4
Level 4A—Routine	26	41.9	69.4
Level 4B—Refinement	11	17.7	87.1
Level 5—Integration	8	12.9	100
Level 6—Renewal	-	-	100

5. Discussion

The previous section highlighted and illustrated the results obtained, i.e., the score of the maritime instructors on the 34 questionnaire items and the six sub-scales aiming to measure their technology self-efficacy. All of the respondents scored more than 4.0 on average on the Likert scale for the TPSA-C21 questionnaire, except for Q.8, 22 and 23. The scores obtained on these three questions were 3.37, 3.47 and 3.47, respectively. These scores were markedly low for any of the questionnaire item scores (refer to Tables 2–7). Although the instructors scored 4.0 or above in the rest of the questionnaire, which offers some evidence that they feel sufficiently proficient in the use of most of the technological tools in their teaching, the relatively lower scores on these questions indicate that instructors do not employ tools that can facilitate collaborative content creation and dissemination, and hint at the reluctance to capitalize on the affordances provided by Web 2.0.

In addition to the above, a non-parametric Kruskal–Wallis test was employed to detect the between-group differences in each of the items for two demographic categories, namely educational qualifications and years of experience. No a-priori threshold was declared for this test; however, it is necessary to compare the noticeable differences in the form of overlap or lack thereof in the mean distributions, as indicated by the obtained chi-square/p-value statistics. The group distribution for the educational qualifications appears to be skewed, and therefore makes it more likely for the respondents to have differences in each item. However, the items, such as Q.3, 4, 5, 10, 13, 14, 18, 19, 20 and 30, showed relatively high chi-square values ($p < 0.01$), indicating that it is more likely that a difference in formal educational qualifications could mean difference in the usage of certain tools or measures, and correspondingly in the self-efficacy in those measures. This could also be the result of differences in the educational curriculum and delivery methods of different maritime universities. For example, the organizational structure, the instructors' formal qualification or their roles within the organization could be different if a maritime institution frequently offers diverse programs in higher levels (e.g., Masters and PhD level) as opposed to regular vocational or bachelor-level courses. For the tests conducted between groups with different years of experience in teaching, relatively lower chi-square values were obtained in comparison to the educational qualifications group. However, in the obtained sample, a relatively smaller difference in the group distribution percentage was also observed for groups with different years of experience, partly explaining such an outcome for the statistical test.

For the measurement model assessment, the guidelines mentioned by Hair et al. [42] were followed and a confirmatory composite analysis was performed. Firstly, the factor loading of each item was checked. The recommended value is greater than 0.708, which was achieved by all of the items except Q.8, 22, 23 and 32. As we can observe from the descriptive statistics, the first three items also received relatively low scores in comparison to the rest of questionnaires, indicating low weightages within the associated constructs. Although Q.32—Sending and receiving text messages—being a generic item, received a comparable score in its mean value, it still has less weightage for the construct's emerging tools. Furthermore, the measures of construct reliability, namely Cronbach's Alpha, Composite Reliability and Rho Alpha, had satisfactory values within the desired interval range from 0.70 to 0.95. The measure of convergent validity, namely the Average Variance Extracted (AVE), was also above the required threshold of 0.50, demonstrating the adequate convergent validity of the constructs. Lastly, the divergent validity was checked using Heterotrait–Monotrait ratios (HTMT). The recommended value, as per [42], is about 0.90. This was exceeded by a noticeable margin when comparing the "Teaching with technology" and "Integrated Applications" constructs in Table 9, indicating that the present measurement exercise and collected data could not satisfactorily distinguish between these two dimensions. Although the limited sample size would warrant caution regarding generalization or inference from this result, it is worth noting for future studies and the usage of the scale.

With respect to the distribution of the respondents according to their classification in the CBAM-LoU self-assessment scales, it is evident from Table 10 that the majority of the responses tended to be clustered around the middle of the spectrum. Most of the instructors (41.9%) identified themselves to be at Level 4A, Routine, i.e., towards being able to comfortably use information technology in their teaching but not having managed to make more efforts to improve their teaching and its impact with use. This was followed by Level 3, Mechanical use (24.2%) of the information technology. None of the respondents marked themselves in the extreme ends of the spectrum i.e., Levels 0, 1 and 6. These results also show that areas of concern exist for the maritime instructors and their utilization of information technologies in their teaching activities. Therefore, the MET institutions could provide more resources and/or training for the instructors for them to advance further on these levels of educational innovation, namely to Levels 4B, 5 and 6. These levels correspond to the refinement, integration and renewal levels of use for technology in the classroom, respectively [40].

The findings indicate that the MET instructors feel sufficiently confident in the use of a majority of the technological affordances available to them; however, there is scope for improvement in their own pedagogical style and in utilizing collaborative knowledge-creating tools, as well as tools that enable the class to engage in a dynamic collaborative learning environment (e.g., social media/wiki/blogs). This facilitates online, distributed modes of learning in some instances of the course work, which is argued to support the acquisition of 21st century skills, such as collaboration and communication in the digital workspace [17]. It is also supported by the socio-constructivist perspective of teaching and learning, in which researchers suggest that knowledge is created in the learning context and then internalized by the student, with peers and technology often acting in mediation [44]. Many researchers have utilized Web 2.0 tools in postgraduate learning settings, with marked improvement in the student engagement in the classroom and innovation in their own practices [45,46]. Similarly, the use of more advanced and interactive technologies such as virtual and augmented reality learning tools deserves further scrutiny to estimate their viability in increasing student engagement and motivation for learning in the classroom context.

The study also highlights the need to focus appropriate attention towards capacity building and technology integration in order for the MET instructors to improve the competitiveness of the MET institutes in general. Too often, and in a majority of cases rightly so, the discussions related to MET quality and value creation hover around the students and their profile, needs and learning style, etc. However, the MET instructors, who form a critical link in the value creation chain of the MET domain, remain under-researched [47]. In this regard, the discussions are often centered around infrastructure development for MET, and seldom on investment in terms of the continuous professional development of maritime instructors. The self-efficacy of maritime instructors towards the integration of technology and reflection towards their pedagogical approach also has implications for the competence development of maritime trainees. Even though the use of technological tools is acknowledged for active and interactive learning, for integrative learning with continuous assessment and for meaningful learning, the challenge for instructors to reflect on their attitudes towards technology is evident [48]. In order to translate their self-efficacy towards technology to meaningful pedagogical changes, [49] suggests that the constructivist orientation for teachers and proper guidance, as well as collaboration in using technological aids, could potentially increase the overall digital intervention in teaching. The increase in the qualifications of the instructors through structured training and capacity building can pay appropriate dividends to the MET institutes as they continue to focus on the pedagogical challenges of the current age with advancements in technology and the changing nature of maritime operations. A formal intervention by stakeholders in the maritime domain and regulatory bodies might be the need of the hour, in the form of changes in the regulations governing the qualifications of the MET instructors to cope with the need to transform maritime educational services and their delivery. Such a move influences the competence of the MET instructors and, by extension, the competence of the students, and also increases the innovation and value creation in the maritime domain. In summary, we would like to propose following recommendations for the stakeholders involved in Maritime Education and Training:

- Ensuring adequate support in the form of resources such as time allocation, and administrative and technical support to maritime instructors in order for them to be able to successfully advance their efforts to integrate technology into their practice.
- Changes in the regulatory frameworks and requirements that acknowledge the need for continuous professional development for maritime instructors specifically with the focus on digitalization and use of Web 2.0 tools.
- Reflection on the pedagogical practices that could provide learning frameworks which support the acquisition of 21st century skills.

The MET institutes should give special consideration in this regard, ensuring that adequate resources and a conducive environment are provided to the maritime instructors in order for them to achieve their goals and objectives for educational programs.

Some limitations of the present study also need to be outlined. Firstly, the sample size of the respondents could have been greater. This would have enabled the even greater generalizability of the results. A greater number of data points could also have enabled the use of inferential statistics (e.g., for regression) in contrast to the primarily descriptive statistics utilized in the study. Secondly, qualitative data in the form of open-ended questions could have been included in the questionnaire, allowing the MET instructors to communicate the reasons or barriers for the limited integration of technology tools in the classroom or their self-reported technological proficiency. Another apparent limitation is that the survey was answered predominantly by Western European nationalities. As such, the obtained data and the results are also a reflection of those geographical regions, and future studies—when conducted involving the rest of the European nationalities—would provide better generalization, along with more data points. Finally, the utilization of questionnaire surveys in itself presents certain limitations. The use of a Likert scale in capturing the responses imposes a predetermined level of granularity on the responses, and deeper interpretation of the data is not possible due to the utilization of this design.

Future studies related to technological integration in the classrooms of MET institutes should be related to the utilization of similar data collection measures in different geographical locations (e.g., in Asia), and should compare them with the European dataset. The more comprehensive modelling of the data utilizing structural equation modelling and regression analysis techniques is also possible if more data measures are included. These efforts could help in a more rigorous analysis of the self-reported technological proficiency of the MET instructors in the region, and the factors affecting it.

6. Conclusions

Maritime Education and Training plays an integral part in global maritime operations. The maritime instructors form a critical link in ensuring the competence development of maritime trainees. The capacity building of the MET instructors can play a vital role in the industry's transformation to deliver on future challenges. This study utilized a validated measure of self-reported technology proficiency, namely the Technology Proficiency Self-Assessment for the 21st Century (TPSA-C21), for the assessment of the technology self-efficacy scores of the MET instructors in the European states (and UK) along six dimensions. The results indicated a scope of improvement for the MET instructors in the better utilization of Web 2.0 tools, such as wiki, blogs and social media, i.e., teaching using a constructivist approach and emerging technologies. The results also highlighted the level of use of information technologies by the maritime instructors in their classrooms and the areas of improvement therein. The further adoption of additional measures into their teaching practices can mean the utilization of collaborative learning techniques in the classroom that bear the potential of better supporting remote and distributed modes of learning in the maritime classrooms. Maritime instructors with a higher level of technological self-efficacy could contribute to the training and education of a 21st century maritime work force that would require an additional and/or differential set of competences. The present study provides a suitable departure point for the further investigation of such topics. Future research should be directed toward gathering more samples from different nationalities, which would enable the greater generalization of the results, as well as comparing different geographical clusters in order to gain further insights for policy interventions.

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Article 3

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IAMU SECTION ARTICLE

Design and implementation of AI chatbot for COLREGs training

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Abstract
The education and training for the maritime industry require renewed focus in the face of technological changes and increasing digitalization. Artificial intelligence presents an avenue for further research that can positively impact efficiency and competence development. Among many applications of artificial intelligence in education, conversational agents or chatbots have gained increased interest in recent years. This paper describes the design and implementation process of "FLOKI"—a chatbot aimed at assisting maritime trainees in learning Collision Avoidance Regulations (COLREGs). For the design of the chatbot, IBM Watson Assistant®—a cognitive computing service—was utilized, which enables the use of Application Programming Interfaces (APIs) in its cloud server. A selected number ($n=18$) of 2nd year B.Sc. in Nautical Science students in a Norwegian maritime university interacted with the chatbot for reflecting on their knowledge about COLREGs. In addition to demographic data, the maritime trainees were asked to answer questions related to user experience utilizing the System Usability Scale (SUS). The findings are discussed along with their implications and future research directions involving AI in maritime education and training.

Keywords Artificial intelligence · Maritime education and training · Chatbot · COLREGs · Digitalization

1 Introduction

The advancements in information technologies and their application have led to the increasing adoption of digitalization and automation in various aspects of the maritime industry (Kitada et al. 2019; Janssen et al. 2021). In continuation to this trend and with the efforts to control and support seaborne ships with remote locations,

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artificial intelligence (AI) will play an essential role in the coming decades through its application in the maritime industry. The future seafarers will be expected to understand and communicate effectively with the various decision support systems enabled by AI (Alop 2019). The education and training of the maritime industry will require a different approach in the face of these changes (Burke and Clott 2016). In addition to the competencies listed in the Standards of Training, Certification, and Watchkeeping (STCW) regulations, maritime stakeholders need to consider cultivating digital skills and AI-enabled education to adequately prepare future seafarers (Sharma and Kim 2021; Baldauf et al. 2016). This study presents a proof of concept for the application of AI in maritime education and training.

Artificial intelligence (AI) has been making steady advancements in recent years and providing various domains with several functional benefits through its use. Although the origin of AI as a concept can be traced back to the 1950s (McCarthy et al. 2006), the recent developments with computing capabilities, advancements in machine learning techniques, and enhanced memory and processing capabilities have led to novel applications in a variety of domains. AI is now being used in finance, healthcare, services, and governance, to provide a few examples of its usage (Buchanan et al. 2020; Ferreira et al. 2021; Sharma et al. 2020; Kouziokas 2017). The basic premise to utilize AI has been its potential to increase efficiency and innovate associated processes in any field of application. However, the use of AI in such applications also puts focus on the role of the associated human element in such instances. Several researchers and professionals have pointed out that with the advent of AI, there would be a parallel trend regarding the need to reskilling the workforce and redefining their roles (Card and Nelson 2019; Rotatori et al. 2021). The AI and its application, in its fundamental premise, is supposed to augment human performance.

A recurring theme around the adoption of AI in workspaces has been regarding the awareness and experience of the individuals with the technology in question, i.e., AI literacy. In this regard, Long and Magerko (2020, p. 2) have defined the term as “a set of competencies that enables individuals to critically evaluate AI technologies; communicate and collaborate effectively with AI; and use AI as a tool online at home, and in the workplace.” They demarcate a set of competencies (human role, data literacy, ethics, etc.) and design considerations (critical thinking, social interaction, low barrier to entry, etc.) to support developers and educators for creating learner-centered AI. Promoting AI literacy, among other considerations, goes hand in hand in with the efforts to advance the technologies in the workspaces and the training of the future workforce. Furthermore, Rahm (2021) has argued in this regard that the relationship between technological development and education is a reciprocal one. While AI literacy is needed as a change in the educational system to enable AI adaption, increased AI literacy by itself can also be utilized to direct the desired technical development in various domains.

One of the primary objectives for applying AI is to improve the learning outcomes in education and training (Pedro et al. 2019). Like other areas of its application, AI brings affordances of greater computing power and tailored delivery of content to the learners. The application of AI in education (AIEd) is closely linked to the advances in the AI domain at large (Zawacki-Richter et al. 2019). Several studies have pointed out the potential of AI to promote engagement, reduce redundant tasks, personalize educational content, and identify emerging learning gaps in the classrooms (Owoc et al. 2021; Schiff 2021). According to Luckin et al. (2016), the AIEd system consists of the domain, pedagogical, and learner models. The strength of AIEd is the fact that the system can select appropriate content from the domain model to the requirements of the learner (model) while also tracking the intermediate interactions (pedagogical model) (Samuelis 2007). Thus, AIEd can enable tailored content delivery suitable to each learner's needs.

1.1 AIEd and application of chatbots

The use of AI in education has occurred concurrently with advances in AI technology itself, offering several functional benefits of its use. AIEd has slowly progressed from personal computers in education to Web-based/online learning systems. The current use of embedded systems and other technologies available through advances in computing power has influenced how education is delivered (Chen et al. 2020). These developments have enabled, among other applications, the use of intelligent conversational agents or chatbots that can perform instructor-like functions in a classroom. Similarly, Timms (2016) has argued that in the future, AIEd will break away from merely education from personal devices to provide new solutions for learning and teaching activities. One of the varied directions AIEd can potentially take will be developing and using "educational cobots" that will be designed to support human instructors. These cobots can keep the learners engaged and answer simple queries the learners might have. Through social network analysis of selected literature related to application of AI in education, Goksel and Bozkurt (2019) have demonstrated that terms like expert systems (ES) and intelligent tutoring systems (ITS), which can mimic human behavior and provide immediate as well as customized feedback to learners, have remained at the forefront for AI-related educational research. With the advances in AI, namely natural language processing (NLP), this concept is being reimagined as intelligent agents or systems that can guide individuals towards the learning objectives and aims and help them navigate the associated process. This is also congruent to the increasing instances of human-automation agent teaming that is taking place in a wide variety of work processes. The larger trend has been towards delegating the tasks of mundane and repetitive nature to intelligent agents. The application of chatbots in education is due to the advances mentioned above in AIEd. In simple terms, the chatbot or conversational agent is defined as a computer program designed to simulate conversation with human agents (Adamopolou and Moussiades 2020). The development of chatbots and their application has been occurring concurrently with AI research. The first known chatbot was developed in the 1960s and was called ELIZA, intended to act as a psychotherapist (Weizenbaum 1966). Since then, there has been a steady progression in chatbot technology, improving the NLP capabilities with various applications in different business/operational cases. Recently, there has been an increase in the research studies that aim to evaluate the application of chatbots in an educational context. In this regard, Okonkwo and Ade-Ibijola (2021) have conducted a systematic literature review regarding chatbot applications in education. They have listed integration of educational content, increased motivation and engagement, ubiquitous access, and simultaneous use by multiple learners as some of the primary benefits of using chatbots in education. They also shed light on some of the challenges that accompany chatbot usage, such as usability and evaluation issues, ethical issues, and programming issues. Similarly, Rapp et al. (2021), adapting a human–computer interaction lens and through their literature review, have identified themes such as trust, expectations, experience, and satisfaction, which are relevant in studies focusing on chatbot and associated interaction issues.

1.2 COLREGs in maritime education and training

The maritime industry is a safety–critical industry with ships moving valuable cargo from one geographical location to another. The consequences of accidents in the maritime industry are often catastrophic, with loss of valuable cargo, environmental pollution, and, in extreme cases, loss of passengers and crew members on board (Schröder-Hinrichs et al. 2012) . There are various frameworks and mechanisms in place to avoid such undesirable events happening and ensure the safety of sea transportation. From the ship's design, guidelines for maritime operations, and the training of seafarers, the maritime industry has adopted various codes and regulations to ensure compliance and promote safety at sea. The seafarers working as crew members play a crucial role in day-to-day operations. Their education and training directly impact the safety of operations onboard (Ziarati 2006). The Maritime Education and Training (MET) domain, which follows the broader framework as stipulated by the Standards of Training, Certification, and Watchkeeping (STCW'74 as amended), ensures the supply of skilled and competent workforce working in the maritime industry. The STCW lists competence requirements for various operational roles onboard (deck officer, marine engineer, ratings, etc.). The mandatory minimum competence requirements for deck officers in charge of the navigational watch are listed in the STCW table A-II/1. There are a total of 19 competence areas that a prospective officer should demonstrate to be deemed worthy for a Certificate of Competency (CoC). Among them, the knowledge of International Regulations for Preventing Collisions at Sea or COLREGs forms an integral part of the operational knowledge required for a deck officer. The COLREGs, also sometimes referred to as "Rules of Road," lists the various regulations that govern the safe movement of maritime traffic. They assign responsibilities such as "Give-Way Vessel" or "Stand-On Vessel" to ships encountering each other at sea. Furthermore, they also list the correct light and sound signals that should be exhibited by different ship types in conditions that apply to them. These rules are crucial in determining the action to be taken by ships when performing navigation (Chauvin et al. 2013). According to the European Maritime Safety Agency, collisions and groundings were the cause of about 25% of maritime casualties in the year 2020 (EMSA 2021). Improper understanding and application of COLREGs can therefore have serious consequences (Mohovic et al. 2016). The MET institutes all across the globe take various measures to adequately cater to the development of good understanding and application of COLREGs during the training period of future deck officers. However, it is also recognized by the maritime stakeholders that various flag states signatory to the STCW differ in terms of educational resources and approaches towards education and training of seafarers. The educational content delivery, tools utilized, and how assessment is carried out for learning outcomes depend upon these factors and are at the discretion of the MET institutes. In Norway, for example, COLREGs training is imparted as part of the 3-year Bachelor's in Nautical Science degree. The COLREGs training forms part of the curriculum in various ways in which specific learning outcomes are expected of the trainees undergoing the 3-year degree. Firstly, the students are expected to remember and understand the different terminologies associated with COLREGs, their framework and historical background, and some of the rule content by heart. Furthermore, the students can develop skills in applying COLREGs in a safe, controlled environment (simulator) where they solve practical assignments and understand the relationship between COLREGs and bridge resource management (BRM). Finally, to further increase the competence and synthesize new ways to use COLREGs to solve emerging challenges in the maritime industry, students can opt to write their Bachelor thesis in a related topic to gain specialization. The above learning outcomes constitute a macromodel of the curriculum in subdiscipline of navigation namely COLREGs as it is conducted in Norway. The culmination of the training occurs when the students go out at sea for 12 months as deck cadets obtaining real-world training in its application before being awarded CoC by the Norwegian Maritime Authority. The COLREGs training, therefore, consists of the demonstration of both innate knowledge as well as practical skills. The knowledge component forms the building block and fundamentals in the understanding of COLREGs. The focus on novel ways to promote understanding and knowledge acquisition can support the overall goal of making the deck officer trainees competent in this important sub-discipline of navigation.

1.3 Pedagogical use of chatbot or conversational agent

There are various pedagogical frameworks applicable and in use for supporting professional learning. The most common characteristic of chatbot in supporting professional educational needs is its ubiquity and simulation of conversations of an instructor or peer. As such, the chatbot or conversational agent is particularly well suited to support self-directed learning (SDL) among individuals. SDL can be defined as a process in which individuals take the initiative in their learning (Knowles 1975). The benefit of using a chatbot is that it can be incorporated in learning instruction design with the discretion of the students. It can support learning activities outside the traditional classroom. The students can pose targeted queries to the conversational agent and get responses. The agent can also promote reflection as dialogue is initiated in the process. Instead of passively learning about COLREGs, the chatbot can promote engagement and offer the students an opportunity to exercise initiative. The chatbot can also act as an additional source of knowledge other than peers and the instructor (Ref Fig. 1). The acquisition of the knowledge component of COLREGs is iterative in nature; and therefore, the chatbot is well suited to support

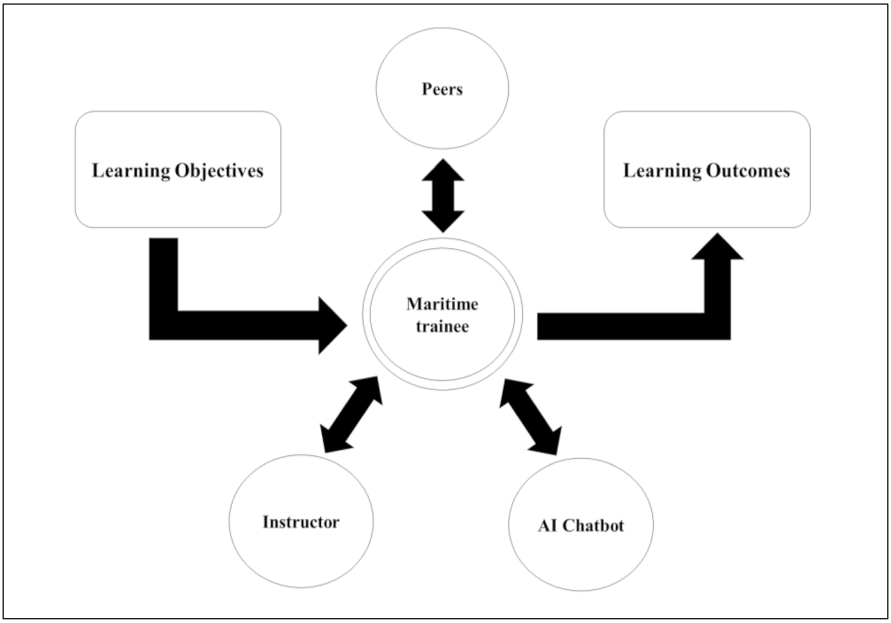

Fig. 1 Student-centered learning activities with chatbot support for self-directed learning

self-directed learning experiences in aiding its understanding. COLREGs are relevant for this context because, in addition to being an essential part of deck officer training, they are also "fixed" in terms of component and their numbers, thus providing sufficient rationale to be designated to an intelligent agent.

In the present study, we, therefore, aimed to design and implement a chatbot for supporting the COLREGs training in the maritime classroom. The primary research objective was to conceptualize and design the chatbot "FLOKI" which can act as an intelligent conversational agent for answering queries related to a selected number of COLREGs. Furthermore, we wanted feedback on the usability of the designed chatbot FLOKI itself. We wanted to understand if it also offers a better user experience in learning COLREGs which is often perceived as a routine and repetitive component of nautical education. For this purpose, a standardized questionnaire known as System Usability Scale (SUS) was utilized. The objective of this study was to provide a "proof of concept" for AIEd in a maritime educational context. The subsequent sections of the paper describe the design and implementation process.

2 Method

2.1 Design of chatbot FLOKI

For achieving the research objective, the chatbot was built using the IBM Watson Assistant service (IBM 2022). It is a service on the IBM Cloud that enables businesses and organizations to build and deploy conversational agents. The service instance was created by the first author on the IBM Cloud and was eventually developed to meet the objectives of deploying a conversational agent that could help the maritime trainees learn the COLREGs. A chatbot or conversational agent has three primary building blocks as per the IBM Watson Assistant service, namely (1) intent, (2) entity, and (3) dialogue. In simple terms, intent can be defined as the purpose of the user's input. Several separate intents have to be described in the chatbot to cater for all possible purposes that the user in question can have to interact with it. The entity refers to an object or term that is related to the intent described by the user and lists all possible synonyms or similar words that can be related to the user's intent. Finally, the dialogue is a response to the recognized intent by the chatbot. It reverts with the response(s) and option(s) to the query posed by the user and enables to supply the most appropriate answers or information that the user queried for initially. These blocks of chatbot work seamlessly together the moment a user query is received by its interface. The intent block matches the query with pre-stored intent. The context of the conversation is stored in the entity block, so that the chatbot "remembers" the conversation's objective, and the dialogue block gives appropriate response to the query. The chatbot during the design phase was titled "FLOKI"—as a tribute to the Norse navigator Floki Vilgerdson, often attributed for discovering Iceland (Thirslund 1997) and providing a maritime persona to the conversational agent. The primary objective of the FLOKI was to enable the discussions of the COLREGs with the maritime trainees; therefore, it was required to input the specific regulations. The International Regulations for Preventing Collisions at Sea (1978 as amended) have 41 regulations and 4 annexes (IMO 2021).

As the intention with FLOKI was to demonstrate proof of concept, only a subset of these rules were selected to be introduced in the chatbot. The authors decided to focus on Rules 11–18, which fall under the Part-B, Section-II, of the regulations and are titled "Conduct of vessels when in sight of one another." The following intents were created for the chatbot—#Greetings, #COLREGs, #thank_you, and #Goodbye. Several examples were provided under each intent to enable the chatbot to capture them. In this step, as per recommendations by the IBM, the first author typed many sentences related to how a student might type a query and stored them as an example under each intent. It is often advised to type as many variations of the query as are possible, including misspelled sentences or typos, to ensure optimum simulation of the actual use case. Furthermore, 8 entities were created, one for each rule, so that chatbot can capture the context and does not "forgets" when intermediate sentences or queries are being directed to it.

Finally, the dialogue block was filled with responses to the expected intent. The main components of this block were the actual COLREGS (Rules 11–18) that were inserted under appropriate headings. These were in textual format; however, some images were also inserted under each rule where applicable to enable a richer response than just plain text and offer better multimedia integration.

The finalization of contents within all three blocks resulted in a hierarchical branching logic flowchart of the chatbot FLOKI which first greets the user with a predefined text describing who it is and its intended purpose, understands the intent of the input, can do customary chit-chat (e.g., "Hello to you, Lets get started!"), returns with the relevant COLREGs when queried, and can also offer conversation ending salutations (e.g., "Goodbye to you"). The IBM cloud service enabled a trial pop-up on the side, which can be used dynamically throughout the process to test how the chatbot is responding. This service was utilized, and several iterations later, the chatbot was deemed suitable for deployment. However, at that stage, the chatbot service was still situated in the IBM Cloud, and to make an actual user case, the service should be hosted in a "real world" environment. For this purpose, a WordPress® site was deployed (www.flokipress.com) and the API integration was enabled with the IBM cloud via a plugin, which resulted in the pop-up of chatbot every time the website was accessed.

2.2 Implementation in a maritime classroom

After the completion of the design and deployment of the chatbot, it was introduced in a regular classroom for B.Sc. in Nautical Science students. An informed consent form briefly describing the purpose of the experiment and a few demographics-related questions were provided in a separate sheet. The summary of the demographic data is provided in Table 1. Participation in the study was voluntary, and no personal information was collected throughout the experiment. The study was conducted on 17 September 2021 with 2nd year B.Sc. Nautical Sciences students at a university which offers maritime education and training (MET) programs in Norway. A total no. of $n = 18$ students participated in the study. The students in the group received an introductory briefing and were given consent forms. After filling out these forms, the students received some additional instructions regarding the use of chatbot FLOKI in a separate information sheet that dealt with interaction instructions and the use of a QR code to access the WordPress site quickly as show in Fig. 2. The students were, therefore, free to select either smartphone or a laptop to interact with FLOKI. After 20 min of familiarization, students proceeded to interact with the chatbot regarding COLREGs Rules 11 to 18. A further 20 min was allotted for conducting this phase of the study (Fig. 3).

The students interacted with FLOKI by first typing customary greetings and then asking specific questions. As per the design of the conversational agent, the input was classified and processed accordingly, and the relevant dialogue block responded with the appropriate rule and supporting images where applicable. The students

Table 1 Demographic characteristics of the respondents

Demographic		Frequency	Percent
Gender	Male	16	88.8
	Female	2	11.2
Prior experience with navigation	Yes	10	55.5
	No	8	44.5
Prior experience interacting with chatbot	Yes	11	61.1
	No	5	27.7
	Can't say	2	11.2

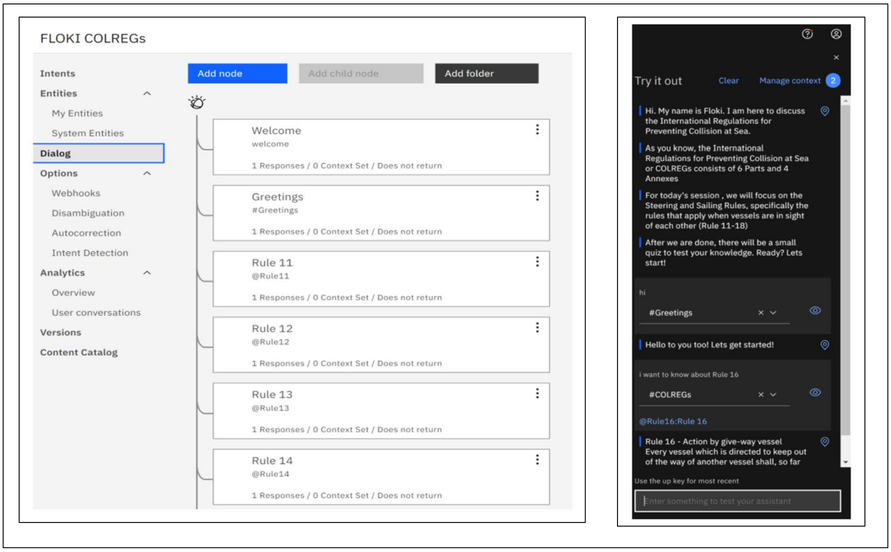

Fig. 2 Design of chatbot with IBM Watson APIs

Fig. 3 Implementation in the classroom and instruction page

practiced in this manner for Rules 11–18 as intended in this exercise and compared the experience with reading rules from a textbook with no interaction (Fig. 4). As originally intended, all of the students could simultaneously interact with FLOKI independently. Some of the students used their smartphones, while some used their tablets or laptop devices for their convenience.

Afterwards, the students were handed another questionnaire—the System Usability Scale (SUS)—to enable the collection of the usability data for the chatbot FLOKI. The SUS is used to provide an overall usability score as per ISO9241-11 on characteristics

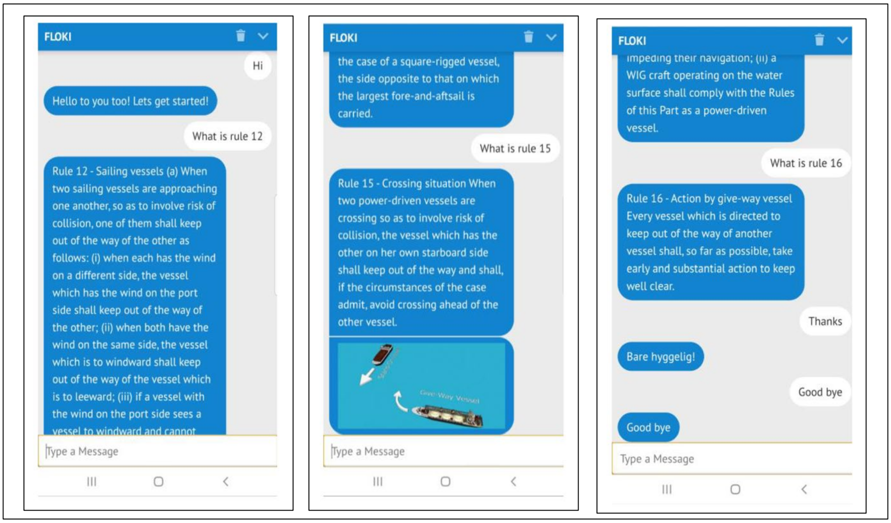

Fig. 4 Example interaction of a student with FLOKI

such as effectiveness, efficiency, and satisfaction (Brooke 1986). The whole exercise was approximately 1 h long for the students—resembling a typical lecture session in the classroom. The collected data was then analyzed using software packages—MS Excel and SPSS. The obtained results, along with the figures and related statistics, are described in the next section.

3 Result

The demographic data of the student respondents is summarized in Table 1:

The usability data of FLOKI was collected through the 18 participating students. For this purpose, a System Usability Scale was utilized. The scale has 10 items, and the respondents were asked to rate each item from scale 1 (Strongly Disagree) to 5 (Strongly Agree) for respective statements. The results are summarized in Table 2:

For calculating the overall usability score, the guidelines given by Brooke (2013) were followed. The guidelines refer to converting all the score to 0–4 scale. For odd-numbered questions, the mean was subtracted by 1 and for the even-numbered questions the mean was subtracted with 5 to compensate for their negative wording. The total of both odd- and even-numbered questions is then multiplied by 2.5.

$$(2.53 + 2.97 + 2.13 + 3.19 + 3.04) = 13.86$$

$$(3.19 + 3.74 + 2.53 + 2.90 + 3.27) = 15.63$$

$$(13.86 + 15.63) * 2.5 = 73.72$$

Table 2 The System Usability scores of the chatbot FLOKI

S.no	Question	Mean
1	I think that I would like to use this chatbot frequently	3.53
2	I found the chatbot unnecessarily complex	1.81
3	I thought the chatbot was easy to use	3.97
4	I think that I would need support of a technical person to use this chatbot	1.26
5	I found various functions in this chatbot are well integrated	3.13
6	I thought there was too much inconsistency in this chatbot	2.47
7	I would imagine that most people would learn to use this chatbot quickly	4.19
8	I found the chatbot very cumbersome to use	2.10
9	I felt very confident in using the chatbot	4.04
10	I needed to learn a lot of things before I could get going with the chatbot	1.73

We calculated the internal consistency of the scale through Cronbach's alpha. The even-numbered questions which were negatively worded were re-coded in SPSS and made to correspond with the positively worded questions. The Cronbach alpha's calculated value was 0.884, greater than the recommended value of 0.700 of scales with a similar number of items (Nunnally and Bernstein 1994).

As some of the demographics data was also collected, we examined this data to investigate if the experience of navigation and experience in the prior use of chatbot had any effect on the perceived usability scores across the groups. To cater for this, we utilized non-parametric Mann–Whitney *U* test scores.

For the groups having experience or lack thereof with navigation on ships, there were 10 respondents stating that they had some experience in navigation and consequently experienced in the practical application of COLREGs, whereas 8 respondents stated that they had no experience with navigation on ships. The average SUS scores for these two groups were 74.97 and 72.70, respectively (Fig. 5).

The Mann–Whitney *U* test showed no significant difference in both groups at 0.05 significance level (U value = 38, Z score = 0.13328, two-tailed) with $p = 0.896$.

Similarly, the respondents stated whether they have any prior interaction with chatbots. A total of 11 respondents replied that they have interacted with a chatbot prior to this exercise, while 7 respondents stated they have not, or they are not sure of this experience. The average SUS scores for these two groups were 78.61 and 66.65 respectively (Fig. 6).

The Mann–Whitney *U* test showed no significant difference in both groups at 0.05 significance level (U value = 21, Z score = 0.15396, two-tailed) with $p = 0.123$.

4 Discussion

The overall usability data for the chatbot suggest that it was received positively by the students in terms of its effectiveness, efficiency, and satisfaction. The median score of usability as obtained by SUS for a large number of product evaluation studies is 70.5 (Bangor et al. 2008) . The chatbot FLOKI, with a score of 73.72, got a

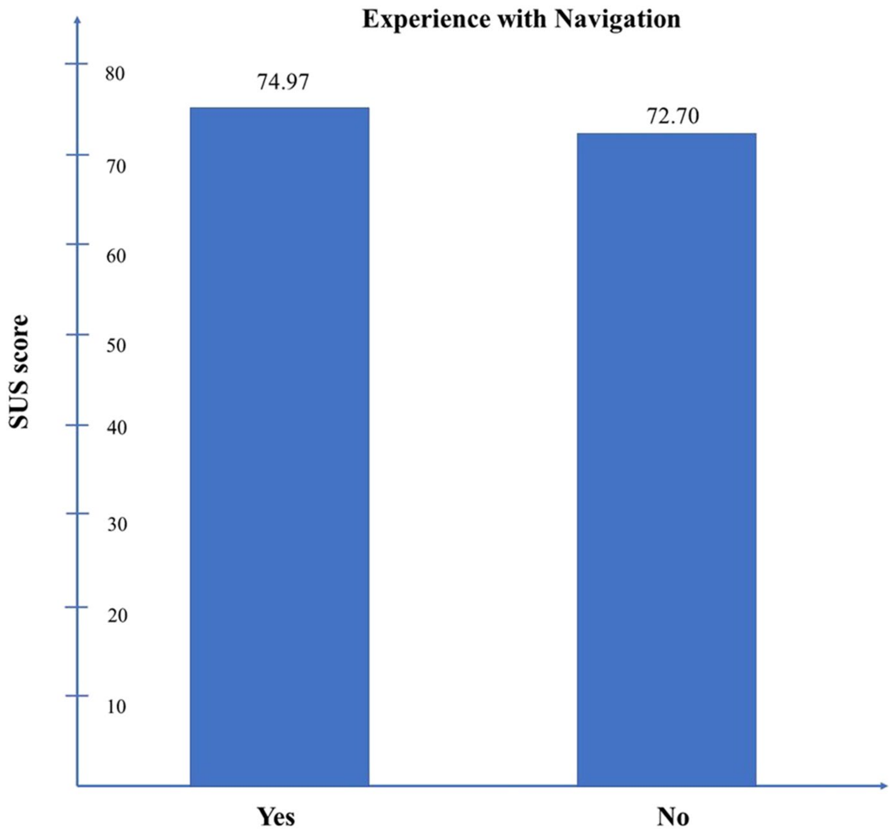

Fig. 5 SUS scores of groups in experience with navigation

higher score than the established benchmark in usability studies. It should be noted that the usability scores out of 100 do not refer to a percentage score. The median score of 70.5 marks the 50th percentile of the established usability benchmark. The score of 73.72 is above the 50th percentile and would lie in the 3rd quartile of the mean scores for the SUS scale. As per the classification given by Bangor et al. (2008) , the rating can be described as "Good"; however, higher ratings of "excellent" (SUS score ranging from 80 to 90) and "best imaginable" (SUS score ranging from 90 to 100) are also present in the continuum. The non-parametric Mann–Whitney *U* test results showed no difference in the usability evaluation of the chatbot by the students who had prior experience in navigation and the use of COLREGs. The difference in the average SUS scores for the students who had prior experience interacting with a chatbot was relatively higher than the group of students with experience in navigation. However, similar to the evaluation between the first sub-groups, a non-statistically significant difference was observed. The findings indicate that prior experience and familiarization with an AIEd tool can influence how the students perceive it; however, more evidence is still needed in this direction.

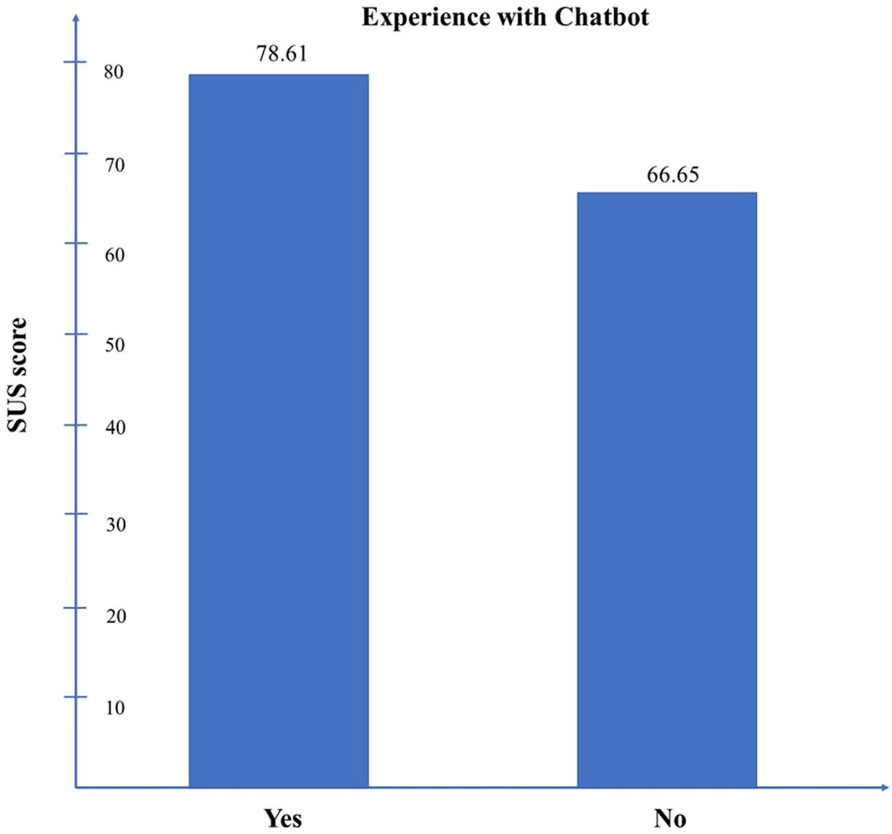

Fig. 6 SUS scores of groups in experience interacting with chatbot

During the informal debriefing session after the conclusion of the study, some of the students did remark that they found the chatbot "interesting" and "novel" for the purpose of studying COLREGs, and they would consider it to be a worthwhile addition in the overall efforts to master the knowledge-related aspects of COLREGs application. Some of the students also mentioned that they found the chatbot "relatable" while interacting with it and would like to practice further to gain a better understanding of the COLREGs. However, as described earlier, the chatbot was trained to respond to a limited number of COLREGs, namely from Rules 11–18. To be truly integrated into the curriculum and for the possibility of future usage, it will be required to further include the dialogue blocks for all of the COLREGs, namely from Rules 1 to 41. Due to the limitations concerning the handling of personal data, advanced features like voice recognition were not considered. Voice recognition with the use of artificial neural networks (ANN) allows the chatbot to have an advanced interface that can communicate with the trainees back and forth through textual medium and recognize their voice inputs and respond accordingly. This would result in a much-improved interaction experience for the students. Advances in natural language processing (NLP) capabilities of the chatbot can also recognize the voice tone and the corresponding emotion of the students, thereby also catering to the students' emotions and respond with appropriate empathy (Suta et al. 2020).

In several countries which are signatory to the STCW, oral examination constitutes a part of the competence assessment of deck officers. For example, the Maritime and Coastguard Agency (MCA) of the UK states that "The oral examination forms part of the assessment of the attainment of all MCA Certificates of Competency, and all candidates must demonstrate an adequate knowledge of English Language" (MCA 2021). This also applies to the demonstration of knowledge regarding COLREGs in the oral examinations related to the Navigation function for the deck officers. Since, this part of the assessment can be thought to be iterative in nature and sufficiently narrow in scope, it has the potential for the application of AIEd tools. Specifically, chatbot FLOKI, with voice recognition integration, can facilitate the self-directed learning process of oral examination preparation for the prospective deck officers. The maritime trainees can utilize the chatbot virtually without limit to master this aspect of curriculum without depending on the instructors or their peers for the support.

5 Outlook and conclusions

The ongoing efforts for introducing digital solutions and support for maritime education and training purposes have to go further than merely catering to the basic knowledge recall and application. To support higher order of knowledge development in various scenarios, digital interactive tools such as those presented in this paper can prove helpful. The stakeholders must understand the potential applications within the maritime classrooms and simulators to optimally use such solutions. The support from artificial intelligence can be considered in light of rapidly evolving educational technology and changing client expectations. Traditional curriculum design affected by technological integration needs to reflect and be inspired by this continuing innovation in the industry.

Some limitations of the current study can be pointed out, and future research directions can be identified. Firstly, the STCW signatory states differ in their approach towards Maritime Education and Training (MET) and the application of technological resources. The current study presented a proof of concept and was carried out in a Norwegian maritime university offering three levels of maritime education for the students. The assumptions towards the use of technological tools such as smartphones or laptops to further support the acquisition of knowledge-related components of B.Sc. in Nautical Sciences could differ from one geographical region to another. The sample size of the study ($n = 18$), in addition to the university-specific context, warrants caution in the exercise of generalization across other regions and to other STCW signatory states. Furthermore, the usability data gathered was compared with the generic benchmarks established in wider usability studies. However, understanding towards application of AIEd tools in MET can further be benefitted by longitudinal studies involving the chatbot FLOKI using the same scale (SUS) and comparing the obtained scores with other AIEd interfaces. The text gathered from the numerous interactions of the chatbot FLOKI can also be subjected to conversation analysis to uncover further the knowledge construction process that unfolds while the maritime trainees attempt to establish their understanding of COLREGs. It should also be noted that the objective of the paper was to illustrate AIEd tool application and COLREGs training was selected as a use case. The COLREGs-related content and its presentation would need further refinement currently to be deemed ready for classroom deployment. Future research should be directed to further investigate the application of AIEd tools to support efficiency, competence development, and self-directed learning in MET and provide a multi-faceted approach to tackle the fast-paced nature of evolution for the required skillsets for professional settings as the maritime domain.

In this study, a proof of concept of AI in maritime education and training—the chatbot FLOKI—was designed and implemented in a maritime classroom. The chatbot demonstrated a use case in the COLREGs training for B.Sc. in Nautical Science students. The 10-item SUS was utilized to gather the usability data concerning effectiveness, efficiency, and satisfaction. The usability data gathered for the chatbot FLOKI shows overall satisfaction in its usage by the maritime students with a usability score in the 3rd quartile of the established benchmark. The obtained SUS score was found to be not dependent on any prior experience of navigation or chatbot interaction by the maritime students. Future research should be directed in further investigation of the potential of AI chatbots such as FLOKI for supporting knowledge components of the B.Sc. in Nautical Sciences education and investigation of avenues in MET at large for application of AIEd to promote efficiency and competence development.

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Declarations

Conflict of interest The authors declare no competing interests.

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Article 4

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Evaluation of digital skills for maritime students

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Abstract

Digital skills have become increasingly important in various sectors such as marine transportation. Changing job demands require the proficiency in digital skills to thrive in an increasingly complex 21st century work environments. Maritime domain has witnessed steady changes in the way education and training is delivered for preparing its future workforce. Novel ways of e-learning and mobile-assisted learning solutions have the potential to transform educational models and facilitate innovation in learning processes. Recently, impact due to Covid-19 and mitigation measures towards continuation of educational delivery also led to accelerated efforts to integrate technology in the maritime classrooms. The prospective maritime students and their digital skills will play a key role in this arena.

The evaluation of the digital skills of maritime students can promote efforts toward greater digital literacy and in turn optimal utilization of novel learning sources. In this study, a standard and validated scale – Youth Digital Skills Indicator (yDSI) was used to evaluate the digital skills of students from a major maritime manpower supplying nation - the Philippines. The digital skills of the maritime students were evaluated along four dimensions – (1) Technical and operational skills (2) Information navigation and processing skills (3) Communication and interaction skills and (4) Content creation and production skills. A total number of 234 valid responses were obtained in this research study. The findings illustrate the relative scores of the students in these four dimensions of digital skills. Furthermore, a Confirmatory Factor Analysis (CFA) was also carried out to assess the measurement model. The statistical findings such as the measurement model fit indices and the descriptive results shed light on the level of digital skills for maritime students in the selected country and can inform the Maritime Education and Training (MET) stakeholders on the potential challenges associated with the digitalization of maritime education.

Keywords: Maritime Education and Training, Digital skills, Digitalization, Industry 4.0

1 Introduction

One of the discernible characteristics of working in 21st-century environments is the emphasis on digitalization. Digitalization can be referred to as incorporating digital technologies into the working environment to improve efficiency and innovate the work processes. In addition to domain-specific skills, digital skills are becoming increasingly important for workers to thrive in these environments [1]. The United Nations Conference on Trade and Development (UNCTAD) have remarked that the digital skills are no more optional in modern work environments [2]. Correspondingly, the educational institutes emphasize using and inculcating digital skills for the trainees undertaking various programs to join the mainstream workforce. Digitalization in education through the usage of advanced Information and Communication Technologies (ICTs) is aimed to meet these objectives. ICT is an umbrella term for digital devices such as personal computers, smartphones, laptops, and tablets interconnected through various networks such as the internet, satellite links, radio waves, etc. Essentially, the learners utilizing ICTs can connect in common platforms whether they are physically co-located or are remotely connected with the learning platform. This phenomenon has therefore led to improved access to education and its delivery on a much greater scale. The global e-learning market has witnessed consistent growth in recent years. It is estimated to reach a total value of 400 billion USD in the year 2026, almost doubling from the size of 200 billion USD in 2019 [3]. The presence of multimedia in learning content also allows a richer experience of interaction for the students when compared to traditional methods. It enables adaptive learning with greater control over the pace of learning for the students and the possibility to communicate with their peers in various modes, in addition to regular face-to-face dialogue. For the teachers and educators, such advances allow them to track better the learning and engagement metrics of their classroom and the program. Notwithstanding these benefits of digitalization in education, some challenges and limitations have also correspondingly emerged out of these advancements. The use of technology can only benefit the learning outcomes if its integrated strategically and pro-actively [4]. Certain additional factors that may impact the realization of potential benefits can be - institutional support, infrastructure, and orientation of instructors [5]. Consequently, there is ongoing debate regarding the efficacy and utilization of digital solutions to training and education [6]. However, it is evident that digitalization transforms the learning experience for both learners and instructors. For the instructors, it offers new modes of learning content delivery as well assessment of learning outcomes. Whereas for the students, it offers personalized learning experience with possibility of online collaboration with peers. The recent impact of Covid-19 and corresponding mitigation measures caused an accelerated push toward the introduction of digitalization in education [7]. To comply with pandemic protocols, it became necessary and compulsory to conduct some part of training and education online for most educational institutions. During such scenario, the approach to offer remote learning solutions differed among institutions as per the level and type of education offered. It was noted that vocational education and training sector required additional considerations in this regard, due to skill based and practical nature of education, as well as its central role in global economy [8].

The Maritime Education and Training (MET) domain can be described as a type of vocational education and training sector that caters to the need of maritime industry. The Maritime industry is responsible for about 90% of the international trade and movement of valuable goods across the globe [9]. The maritime industry is often characterized as a truly global industry. For example, a ship can be built and commissioned in one country and be manned by seafarers of another country while carrying cargo for a third country, between any two ports in the world [10]. Additionally, the maritime industry has unique operational requirements due to its dynamic nature of work. Therefore, digitalization in operations is naturally expected to be leveraged in the maritime industry to maintain adequate communication and operational links with the high value asset such as ships. The safe and efficient operation of ships depends on the knowledge and skillset of the seafarers onboard to a considerable extent. The seafarers employed in such high value assets need to have high standards of professional education and training due to safety aspects. In recent years, the training and education framework for the seafarers working in the ship has witnessed an evolution to match the changing operational aspects of shipping [11,12]. Nonetheless, the seafarers are operating in an increasingly technology-rich environment. In addition, due to advances in ship technologies, maritime education is being offered as a combination of on-the-job training and shore-based training. The MET can be described as having both theoretical and practical components which the seafarers need to be proficient in [13]. Usually, the theoretical component of education and training is conducted on shore while the practical component is mastered onboard. However, due to improved internet and satellite connectivity, it is now possible for seafarers to continue some aspects of theoretical training in the form of Computer Based Training (CBT) even while onboard. Conversely, some practical components can be acquired through the use of simulators while at shore. These developments have enabled ubiquitous learning solutions and continuous professional development. Some noticeable advances in this regard have been the use of mobile learning solutions enabled by smartphones and tablets and the use of Virtual and Augmented Reality for simulation [14]. The use of such digital technologies, as mentioned above, also allows the trainees to jointly partake in the learning exercises and even enables them to take the initiative in the experience. A noticeable trend towards increasing use of digital learning solutions whether onboard or at shore is observed. Despite these developments, it is noted that emphasis on digital literacy or digital skills of the maritime trainees is not explicitly addressed in the current Standards of Training, Certification and Watchkeeping (STCW) framework [15]. As the maritime industry enters the era of industry 4.0, the mode of vessel control and operation will witness a fundamental shift towards those marked by interconnected digital systems with the role of seafarers relegated to increasingly supervisory control [16]. Proficiency in digital skills will form an important component for the transition and reorganization of job roles for the seafarers.

Considering these facets of shipping, it is of considerable interest for Maritime Education and Training (MET) institutions and stakeholders to take into account the digital skills of the maritime trainees along with the regular operational skills. Lack of focus towards digital skills could lead to a digital divide for the MET community which could eventually translate into skills gap [17]. Furthermore, the need for maritime trainees to possess adequate digital skills is also related to their future employability and career progression. To support the development of digital skills for the maritime trainees and charting out a roadmap to address some of the above discussed issues, it is first necessary to identify frameworks which allows adequate measurement and evaluation of these digital skills. The present study is aimed to contribute to this specific thematic area in MET. In this paper, a standardized and validated scale – Youth Digital Skills Indicator (yDSI) is utilized to measure the digital skills of the maritime trainees [18]. The yDSI measures the digital skills of the respondents in four dimensions – (1) Technical and operational skills (2) Information navigation and processing skills (3) Communication and interaction skills and (4) Content creation and production skills. The primary research question which was posed was – What is the current level and proficiency in digital skills of maritime trainees? For the purpose of this study the scope was narrowed down to include an example case of a major maritime workforce supplier nation – the Philippines. It is recognized as one of the largest suppliers of both officers and ratings in the global pool of working seafarers [19,20].

In the next section, the need for focusing on the digital skills of the maritime trainees is described in greater details along with the generic 21st century skills requirements for modern vocational education and training, before describing the methodology and findings originating from the current work.

2 Background and Literature Review

The labor market for any domain is usually in a state of constant flux as it evolves and adapts to the global economy, which itself is bound to change due to a variety of factors. In the contemporary era, some of the factors which are impacting the labor market in general can be listed as – globalization, demographic shifts, digitalization and climate change [21]. An unforeseen but equally impactful factor has been the Covid-19 pandemic which dramatically affected the functioning of various industries and businesses. While the impact of Covid-19 pandemic has been disruptive and complex to assess in certain instances, a noticeable trend had been the adoption on digital technologies for carrying out various job functions to comply with pandemic protocols. It has led to increase in emergence of activities such as remote work, online education and e-commerce to name a few. However, it can be argued that Covid-19 pandemic merely acted as a catalyst to already existing mega-trends in the global economy where digitalization as a phenomenon was occurring for the past few years. The current era of industrial transformation is also referred to as “Industry 4.0” which can be defined as “organizational and technological changes along with value chains integration and new business models development that are driven by customer needs and mass customization requirements and enabled by innovative technologies, connectivity and IT integration.” [22, p.849]. A key characteristic in industry 4.0 is the inter-connectivity of various sub-systems enabled by the Information and Communication Technologies (ICTs) as well as the focus on automation of various job functions which leads to less labor-intensive alternatives. The operational environments and businesses are increasingly embracing digitalization as a measure to improve their overall efficiency. As a result of industry 4.0 related developments, corresponding changes in the work profile and job requirements are occurring in some of the impacted sectors. While the overall effect following the use of new technology is improvement in efficiency, the process also leads to changes in the job profiles and consequently the skills requirements for the new roles [23]. Digitalization leads to a decrease in “lower” skill requirements while the routine and repetitive aspects of work are automated. Whereas it leads to demand in “higher” skills which are related to monitoring, interaction and decision making with the digital systems. As the job requirements change for any role, there is corresponding need for the employees to be trained for performing in the new and adapted roles. Failure to respond to the new job requirements can lead to a deficiency in supply and demand of these new roles, which in simple terms can be described as a situation of skills mismatch in the industry. Skills mismatch in the industry, at various levels is undesirable, as it translates to losses in economy and value creation in society at large. Furthermore, there is usually a time lag between the changing skills demand and the response in equivalent training delivery. According to the International Labor Organization (ILO), one of the most important preventative measures to avoid skills mismatch is to anticipate future skill gaps [24]. It is important for the industry stakeholders and policy makers to determine the future skills requirement for ensuring that the industry remains competitive and resilient in the face of disruptive changes due to the advancement of technologies and other external factors.

The maritime industry has also experienced operational changes as the result of the industry 4.0 transformations. Some of the key trends in relation to industry 4.0 and maritime domain has been developments in relation to - smart ports, digital twins, blockchain adoption, autonomous vessels and 3D printing to name a few [25,26]. From an operational perspective, the trend regarding the development of autonomous vessels is the most relevant in terms of anticipating future skill requirements, as it can have impact on the employment of the seafarers working at the sharp end. Autonomous vessels, as the name suggest, describe a type of ships that are highly automated and operate quasi-independently with only monitoring from human operators being required. The conceptualization of such vessels is materializing in the maritime domain with the projects such as - Yara Birkeland and Zhi Fei [27]. However, it can also be stated that developments in relation to increasing automation and consequently a reduction in crew size have been taking place in maritime domain for few decades, and autonomous shipping represents the next step change of such trends. For example, during the second half of 20th century, due to factors such as - mechanization of deck, unitization of cargo, automated boiler control, development of RADAR/GPS and other advances, significant reduction of crew size in merchant shipping was observed [28]. At the start of the 21st century, the ships experienced continuous digitalization due to advances such as e-navigation and unmanned machinery spaces which led to further reorganization of job tasks and overall reduction of crew size [29,30]. Consequently, the training of the seafarers also changed as a response. The navigation officers onboard are now trained in the use of systems such as - Electronic Chart Display and Information System (ECDIS), Automatic Identification System (AIS), Global Positioning System (GPS) and so on. For example, the act of determining position of the vessel which used to be a process taking several steps and involving paper charts, has now transformed into only monitoring of the processed information by the bridge equipment on the digital screens. The priority for navigation officers is now given towards training them for operating such digital systems, understanding their limitations and managing cognitive resources through Bridge Resource Management (BRM) and similar measures. The domain of Maritime Education and Training (MET) has also witnessed changes in the way, seafarers are prepared for these new roles. For example, a trainee navigation officer, in addition to onboard training, can also complete a significant amount of training through the use of simulators. The immersivity and fidelity of the maritime simulators have correspondingly increased to offer more realistic recreation of operational environments over the years [31]. Additionally, due to improved internet connectivity and proliferation of digital devices such as desktop and laptop computers, Computer-Based Training (CBT) has also been widely adapted for the purposes of instructional delivery [32]. These trends show increasing impact of digitalization in both operational and educational aspects of maritime industry.

There are several research articles that have drawn attention to the new operational environment where prospective seafarers will operate due to ongoing automation and digitalization in the maritime domain. For example, Shahbakhsh et al. [33] recognized the important trends in the shipping sector with regard to continuous digitization and indicated that the next generation of shipping will demand significant mediation of human and technology agents through digital interfaces. In such a scenario, the demand for basic digital literacy as a core knowledge for the seafarers would be a realistic necessity. Similarly, Alop [34] argued that competency in ICT skills, in addition to the conventional maritime operational knowledge, will be critical in preparing the maritime industry for an intelligent shipping environment. However, all of the aforementioned papers are conceptual in nature, and the MET stakeholders are yet to develop a more realistic approach to identifying the significance of digital skills for potential maritime trainees. Corresponding efforts towards upskilling of the maritime students are required to ensure fulfillment of job requirements. Improved digital literacy or proficiency in digital skills can assist the maritime trainees to meet the job and training demands and succeed in the evolving environment of this safety critical domain. An initial step in this regard would also be to conduct investigation regarding the present levels of digital skills and identify standard frameworks and instruments to measure the same.

The need for the digital skills of the maritime trainees should also be considered in light of the changing skills requirements for the technical vocational education and training arenas in general [35]. A generic set of skills, commonly referred to as the 21st century skills have been described by educational stakeholders and policy makers to be vital for preparing the workforce for future. 21st century skills refer to a particular set of skills that educational researchers claim are necessary to succeed in the modern knowledge based economy. There are various frameworks and definitions given in the existing literature regarding what specific skills might comprise in this set. For example, The Organization for Economic Cooperation and Development (OECD) in their 2009 working paper stated that the 21st century skills can be divided broadly into two dimensions – (1) information dimension and the (2) communication dimension [36]. They further describe distinct skills which belong to these two dimensions.

Skills such as information literacy, creativity and innovation, problem solving, decision making, research and enquiry, and media literacy were listed as belonging to the information dimension. Whereas skills such as critical thinking, collaboration, flexibility, ethics and social responsibility were denoted as belonging to the communication dimension. In contrast, the European Union (EU) have put forth a number of “key competences” for life-long learning that will be necessary in the 21st century. It is stated that these key competences consist of well-defined knowledge, skills and attitudes and are equal in their importance for all round development of the EU citizens. The key competences are listed as – literacy competence, multilingual competence, mathematical competence and competence in science, technology and engineering, digital competence, personal, social and learning to learn competence, citizenship competence, entrepreneurial competence, and lastly, cultural awareness and expression competence [37]. Another highly cited source with reference to the 21st century skills is the P21 (Partnership for 21st century skills) framework [38]. The P21 Framework for 21st Century Learning was established with input from academics, education experts, and industry leaders to describe and illustrate the skills, knowledge, expertise, and social infrastructure students require to succeed in their careers, lives, and citizenship. It divides the required 21st century skills into three distinct themes – (1) Learning and Innovation skills (2) Information, media & technology skills and (3) Life & Career skills. Some examples given under learning and innovation skills include – creativity & innovation, communication, critical thinking and collaboration. Examples of Information, media & technology skills include – Information literacy, media literacy and ICT literacy. Whereas examples of life & career skills are given as – flexibility, adaptability, productivity, accountability, social & cross-cultural skills and so on. As can be seen in the above frameworks, the requirements related to digital skills have been consistently mentioned as being necessary for 21st century work environments. Digital skills will play a vital role in work and civic life in the coming years as the industry and society gradually adapt digitalization and transform itself.

There are various existing frameworks which have been devised for the purpose of assessing the digital skills of individuals. Carretero, Vuorikari and Punie [39] have classified them into four types – (1) performance assessment (2) knowledge-based assessment (3) Self-assessment (4) Secondary data gathering and analysis. For the purpose of this research, only self-assessment-based frameworks were considered. In this regard, there are some established questionnaires and instruments available. For example, EU project administered by Joint Research Centre has formulated a framework called - The Digital Competence Framework for Citizens, also referred as “DigiComp”. It measures the digital skills of the respondents in five dimensions – such as (1) Information and Data literacy (2) Digital Content Creation (3) Problem Solving (4) Communication and Collaboration and (5) Safety. The project was piloted in 2010 and has now had four iterations with the latest framework known as DigiComp 2.2 which was released in 2022. It has been useful for the purposes of creating training materials, identifying individual profiles and designing competence assessment tools [40]. The International Telecommunication Union (ITU) has formulated a digital skills toolkit which divides the digital skills of an individual into three levels – (1) Basic (2) Intermediate and (3) Advanced which captures the proficiency in digital skills from a foundational level which involves basic digital tasks such as operating the digital devices and handling the data to relatively advanced topics such as - mobile app development, handling big data and knowledge related to artificial intelligence. However, as the focus of the investigation in this paper was towards measuring the self-reported proficiency of students with clear operational definition of digital skills related to learning and teaching tasks, the framework as developed by Helsper et al. [18] was selected. The yDSI indicator originated recently from an EU project titled ySKILLS, with its aim to maximize the digital skills development of the youth. The yDSI scale is a cross-nationally validated scale which has 25 items based on conceptualization of various dimensions of the digital skills that should be acquired by the students for enabling them to utilize the digital resources for their learning.

3 Methods

The Youth Digital Skills Indicator (yDSI) questionnaire was digitalized for administering to maritime students enrolled in Bachelor of Science courses at several Maritime Education and Training (MET) institutes in the Philippines to achieve the research objective. As described earlier, yDSI questionnaire assesses digital abilities in four dimensions: (1) technical and operational skills, (2) information navigation and processing skills, (3) communication and interaction skills, and (4) content creation and production skills. The questionnaire was digitalized using the *Nettskjema* platform and delivered via the network of the industrial partner of the affiliated institute - *TERP AS*. The industrial partner is an established digital solutions provider for MET in the Philippines. The questionnaire included a brief explanation of the project's goal and acquired informed consent from all respondents. The information was gathered between the dates of 10.03.22 and 20.03.22. There were 270 responses received in total. Due to straight-lining, 36 responses were eliminated, leaving 234 responses to be considered for the final data analysis. There are various guidelines regarding the minimum sample size for CFA. Usually, studies suggest a sample size of at least 200 responses when conducting CFA and this condition was adequately met [41,42]. Thereafter, software packages SPSS©, SmartPLS4© and MS Excel© were used to examine the data. First a frequency and percentage distribution of responses as rated by the participants from "Not at all true of me" (1) to "Very true of me" (5) was tabulated. It should be noted that the questionnaire had two additional responses such as - "I do not want to answer" and "I do not know what you mean" also included to cater for social desirability bias. Therefore, the respondents had the opportunity to choose from 7 values in the scale. The obtained responses were then categorized accordingly using descriptive statistics and visualized in the form of bar graphs as shown in Figures 1-4. The demographic data of the respondents, in terms of age, gender and discipline (B.Sc. Nautical science or B.Sc. Marine engineering) is given below in Table 1:

Table 1. Demographics of the respondents

Gender	**Male**	**Female**
	221 (94.4%)	13 (5.6%)
Discipline	B.Sc. Nautical	B.Sc. Mar.Eng.
	210 (89.7%)	24 (10.3%)
Avg. Age	21.11 years	S.D = 0.73

Further a confirmatory factor analysis (CFA) was used to evaluate the measurement model in addition to collecting descriptive data. CFA is a popular statistical approach in the research literature for providing support for construct validation [43]. For calculating the CFA fit indices and the path diagram, SPSS AMOS version 23 software package was utilized. The path diagram as given in the Figure 5 was drawn with four dimensions of the digital skills as described in the yDSI scale were drawn in AMOS with each having six related items under them. An error term "u" was assigned for each variable (item) and its regression weight value was set to 1. Subsequently, under the "Object properties" menu, calculate estimates button was selected and checkboxes of desired relevant parameters such as standardized estimates and squared multiple correlations were ticked before clicking on the button to view the final output.

4 Results

The obtained results are described below in the form of bar graphs, tables and CFA model along with the fit indices.

4.1 yDSI – Technical and Operations skills

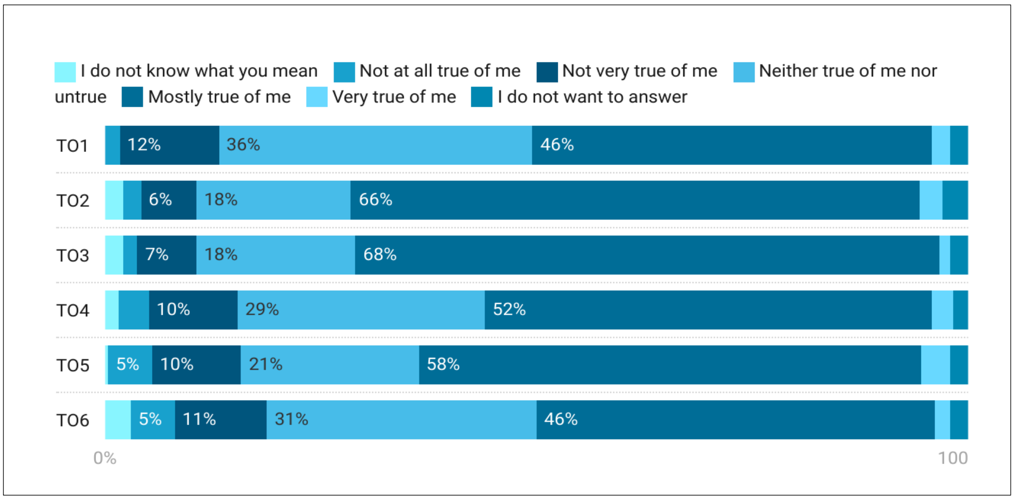

Figure 1. Technical and Operational Skills – Frequency percentage distribution

Table 2. yDSI scale dimension Technical and Operational skills

S.no	Item description	Factor loading	Itm-tot. corr.	AVE	CR	Cronb. α
TO1	I know how to adjust privacy setting	0.614	0.569			
TO2	I know how to turn off the location settings on mobile devices	0.664	0.696			
TO3	I know how to protect a mobile device (e.g. with a PIN, a screen pattern or a finger-print)	0.682	0.693			
TO4	I know how to have the same documents, contacts and apps on all devices that I use	0.687	0.714	0.434	0.821	0.849
TO5	I know how to use private browsing (e.g. incognito mode)	0.599	0.598			
TO6	I know how to block unwanted pop-up messages or ads	0.699	0.547			

4.2 yDSI – Information Navigation and Processing skills

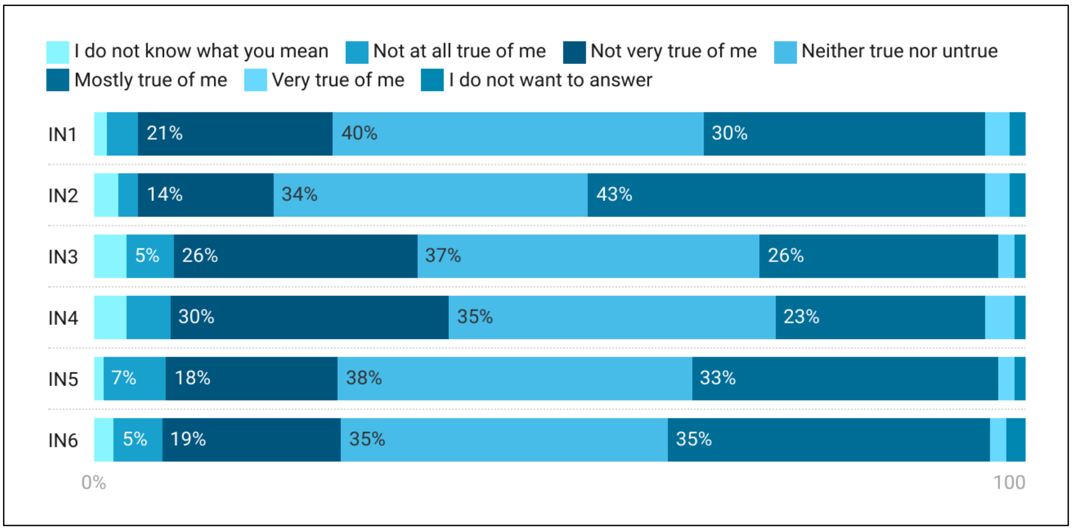

Figure 2. Information Navigation and Processing Skills – Frequency percentage distribution

Table 3. yDSI scale dimension Information Navigation and Processing skills

S.no	Item description	Factor loading	Itm- tot. corr.	AVE	CR	Cronb α
IN1	I know how to choose the best keywords for online searches	0.732	0.584	0.464	0.836	0.872
IN2	I know how to find a website I have visited before	0.626	0.654			
IN3	I know how to find information on a website no matter how it is designed	0.778	0.666			
IN4	I know how to use advanced search functions in search engines	0.770	0.685			
IN5	I know how to check if the information I find online is true	0.605	0.759			
IN6	I know how to figure out if a website can be trusted	0.541	0.693			

4.3 yDSI – Communication and Interaction skills

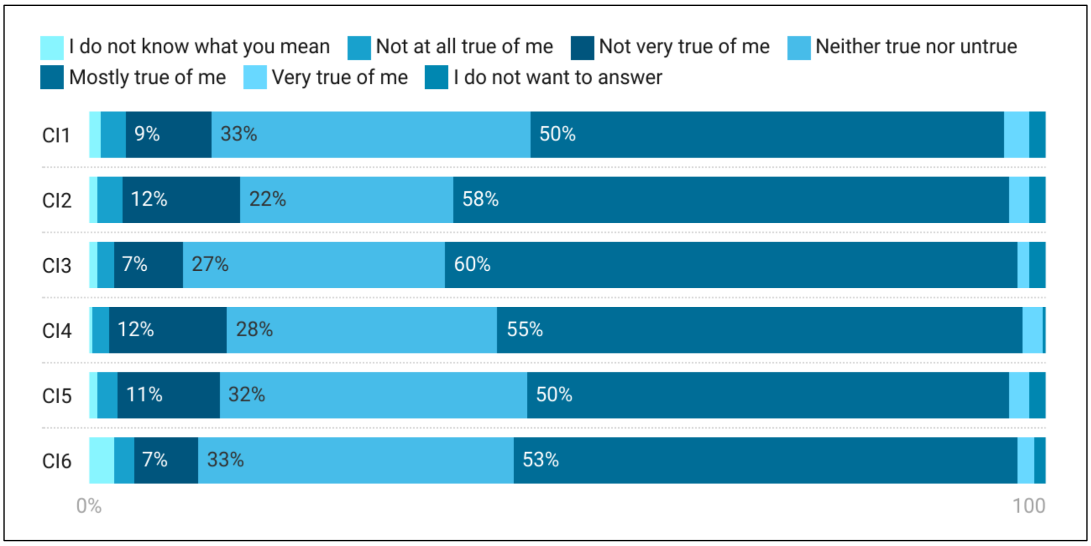

Figure 3. Communication and Interaction Skills – Frequency percentage distribution

Table 4. yDSI scale dimension Communication and Interaction skills

S.no	Item description	Factor loading	Itm- tot. corr.	AVE	CR	Cronb. α
CI1	Depending on who I want to communicate with, I know which medium or tool to use (make a call, send a WhatsApp message, send an email, etc.)	0.710	0.744	0.524	0.867	0.910
CI2	I know when to mute myself or disable video in online interactions	0.766	0.780			
CI3	I know which images and information of me it is OK to share online	0.846	0.783			
CI4	I know when it is appropriate and when it is not appropriate to use emoticons (e.g. smileys, emojis) or text speak or capital letters	0.754	0.774			
CI5	I know how to report negative content relating to me or a group to which I belong	0.573	0.677			
CI6	I know how to recognize when someone is being bullied online	0.662	0.750			

4.4 yDSI – Content Creation and Production skills

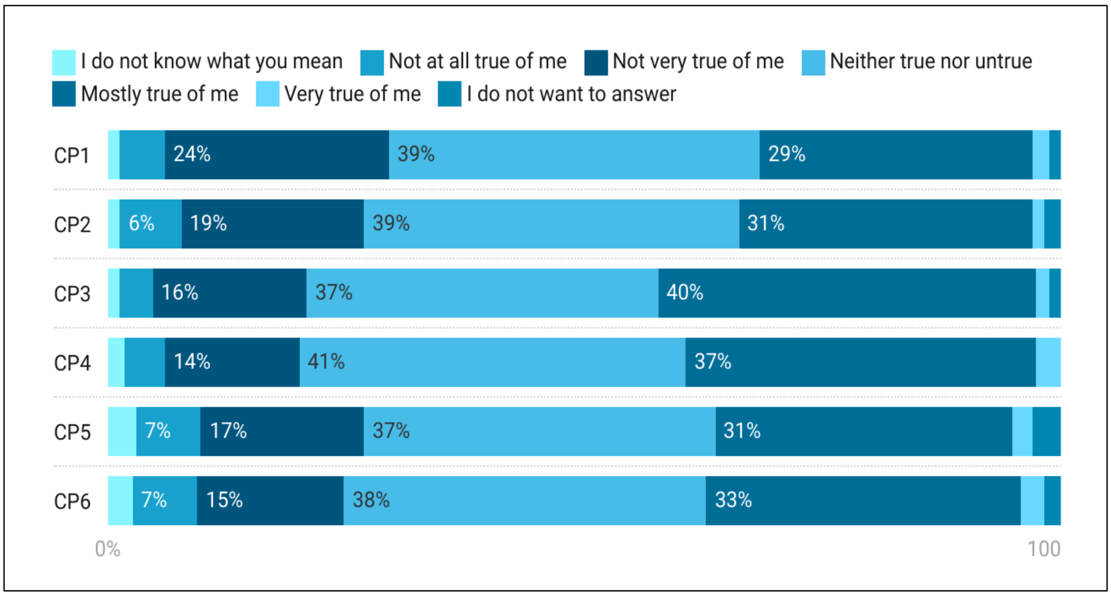

Figure 4. Content Creation and Production Skills – Frequency percentage distribution

Table 5. yDSI scale dimension Content Creation and Production

S.no	Item description	Factor loading	Itm-tot. corr.	AVE	CR	Cronb. α
CP1	I know how to create something which incorporates different digital media (images, music, video, GIFs)	0.528	0.621	0.389	0.787	0.857
CP2	I know how to edit existing online images, music and videos	0.587	0.652			
CP3	I know how to ensure that many people will see what I put online	0.448	0.642			
CP4	I know how to change the things I put online depending on how other people react to it	0.621	0.728			
CP5	I know how to distinguish sponsored and non-sponsored content	0.758	0.665			
CP6	I know when I am allowed to use content covered by copyright	0.740	0.582			

4.5 yDSI – Confirmatory Factor Analysis (CFA) results

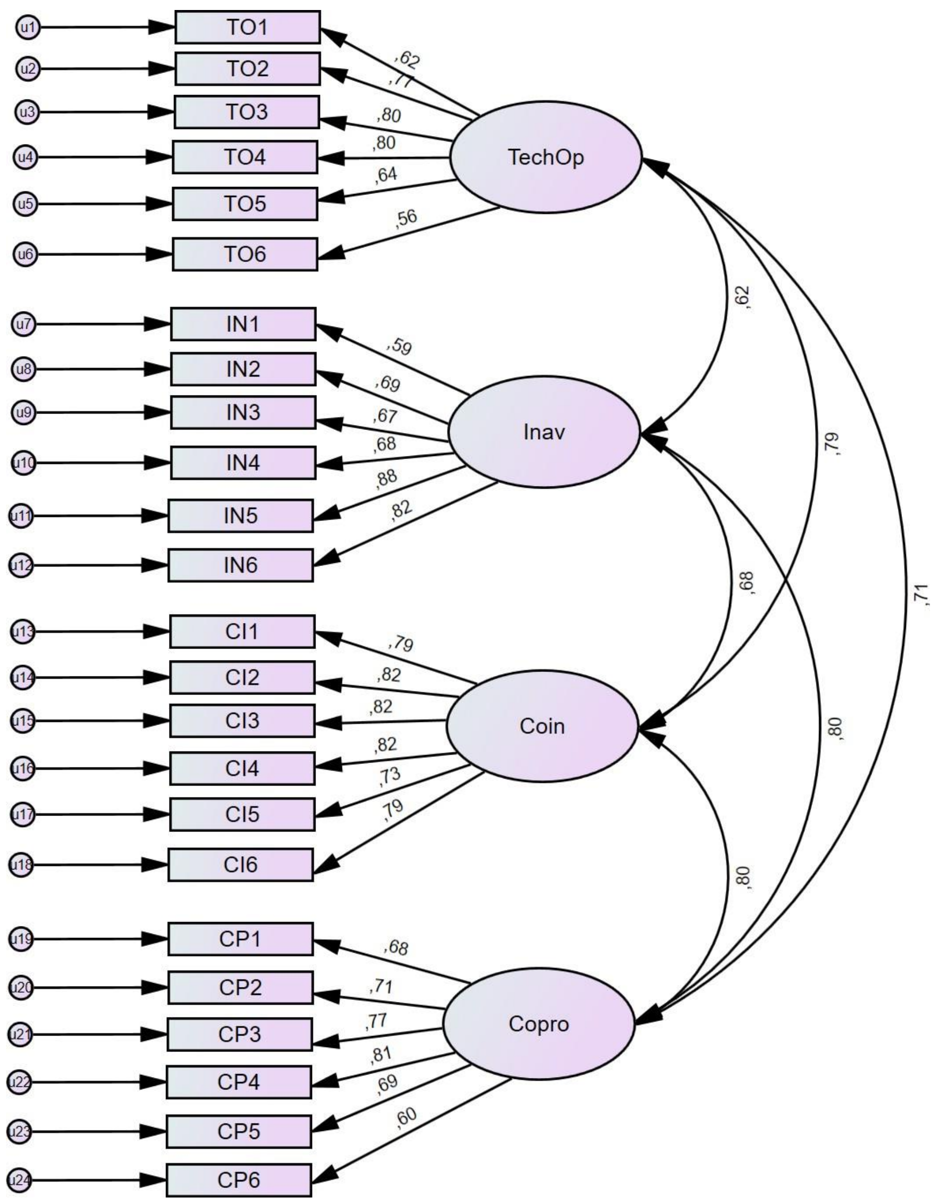

Figure 5. CFA path diagram of the yDSI scale

Table 6. CFA fit indices

Indices	Value
$\chi 2$	597.75
df	246
Sig.	0.000
RMSEA	0.078
RMR	0.063
CFI	0.895
TLI	0.882

Note - $\chi 2$ = Chi square, df = degrees of freedom, Sig = significance level, RMSEA = root mean square error of approximation, RMR = root mean squared residual, CFI = comparative fit index and TLI = Tucker-Lewis index

4.6 Reliability and Validity

The theoretical structure of yDSI was also evaluated through confirmatory factor analysis. The description of each item from the four dimensions of the yDSI scale and the values obtained from the confirmatory analysis are provided in Tables 2-5. For the ease of description, the short form of the factors is provided such as - TO, IN, CI and CP. Each of the factor in turn have 6 items under its description as given in Tables 2-5. Therefore, each item falls under one of these categories: TO (1-6), IN (1-6), CI (1-6) & CP (1-6). As can be observed, except CP3, all other items demonstrated a factor loading greater than 0.5 for their respective dimensions. The item-total correlation for all the items were between 0.5 - 0.8, demonstrating adequate internal consistency. For assessing the convergent validity, which is measured using Average Variance Extracted (AVE), a threshold of 0.5 is often set. It can be seen that except the dimension communication and interaction skills, none of the remaining dimensions exceeded this threshold. However, if the AVE is less than 0.5 of a factor, but its composite reliability is greater than 0.6, the convergent validity is observed as adequate [44]. The composite reliability (CR) values of the factors ranged between 0.79 – 0.87. The Cronbach’s alpha values which indicated reliability measure of the factors ranged between 0.85 – 0.91, indicating a good level of reliability [45]. The path coefficient values between the item and the factor and between the factors themselves ranged between 0.56 to 0.82 as can be seen in the Figure 5. The CFA fit indices are summarized in the Table 6. As can be observed in the table, the $\chi 2$ to df ratio is 2.43, which is below the established threshold of 3 and therefore is deemed acceptable [46]. The RMSEA value obtained was 0.078. The preferred RMSEA value in the literature is 0.05, however, a value below 0.08 is acceptable and represents reasonable error of approximation [47]. Similarly, the RMR value of 0.063 was below the commonly used threshold of 0.08. The CFI and TLI values were 0.895 and 0.882. Although for these indices a value equal or greater than 0.90 is preferred, the obtained values as can be seen are close to cut-off [48]. A greater sample size could have been more suitable for evaluating fit; however, it can be seen from the obtained indices that a reasonable performance of the theoretical model was observed.

5 Discussions

As observed from the descriptive results and the bar graphs of the four dimensions of digital skills, it can be noted that the students have rated their proficiency in technical and operational skills and communication and interaction skills higher than their proficiency in information navigation and processing along with content creation and production skills. For example, if we observe the proportion of responses obtained for the Likert scale value “4”, which would imply that the statement is “Mostly true” for the student, indicating a reasonable level of proficiency in digital skill item in question, as given in Figures 1-4. For the dimension – technical and operational skills, these values ranged from 46-68%. Whereas, for the dimension – communication and interaction skills, the values ranged from 50-60%. In contrast for the dimension – information navigation and processing skills, the value ranged only between 23-43%. Similarly for the dimension content creation and production skills, these values ranged from 29-40%. An avenue of potential improvement can therefore be identified in the latter two dimensions. It indicates that the students are relatively unsure regarding how to seek pertaining information during interacting with digital media and evaluate its credibility. Furthermore, relatively low scores in the content creation and production dimension indicates that the students are unsure regarding how to produce digital content which can be incorporated in their education and related copyright issues. While the students feel relatively confident in elementary uses of technology such as operating the digital devices, manipulating the files, navigating the system architecture, using the ICT technologies for everyday communication and sharing the resources, they might feel less proficient for transformational uses of the same technology for creating their own learning resources, editing them, verifying accuracy of information obtained and understanding handling of intellectual property. For the former case, it implies that to support the higher order discussions in the classroom instruction and curriculum design, relative low score on the above-mentioned dimensions could present a possible bottleneck for orienting students to create and evaluate knowledge. Due to an increase in digital distributed modes of learning content delivery, novel opportunities to create scenarios and exercises would present themselves where the self-directed learning process can be led by the students and facilitated by the instructors. Without catering to these factors related to digital content engagement by students, any proposed solutions in instructional delivery or effort in educational innovation will have only limited impact. However, relatively less score on the latter dimension can also translate to unforeseen results such as cybersecurity lapses. For example, the “NotPetya” cyber-attack on the shipping company Maersk in 2017, led to not only heavy losses to the organization, but also presented a logistical challenge for several ports around the world [49]. It is difficult to foresee how the new risks in the maritime cyber-security domain would evolve. Despite this, the basic awareness of cyber-security for the maritime students can be built on an adequate level of digital proficiency in this regard, specially related to information navigation and its processing. The relatively low levels of digital skills in the information navigation and content creation dimensions of digital skills can also be compared with the pedagogical model given by Bloom [50]. According to the Bloom’s taxonomy, there are six hierarchical levels of cognitive processes which should be tied with specific educational objectives – (1) Remember (2) Understand (3) Apply (4) Analyze (5) Evaluate and (6) Create. The low levels of information navigation and content creation skills could potentially affect the levels 5 & 6 of the Bloom’s taxonomy. In other words, while the students may perform satisfactorily with the elementary level of tasks, relatively higher level of engagement with the learning content may not occur on the account of low skills in these dimensions. It may have implications for introducing and adapting digital medium in the maritime classrooms and therefore requires cognizance from the MET stakeholders to address this area satisfactorily. Targeted training and workshops by the shipping management companies for their crew could be argued as a possible response, however, more favorable changes could come through regulatory advances related to maritime education and training, which explicitly take into account the need to cultivate digital skills of seafarers.

The present study was an exploratory study which evaluated the digital skills of maritime trainees using a standardized instrument. Some existing limitations of this research study should also be acknowledged. Firstly, a greater sample size could have resulted in better generalization of the results. The obtained results from the CFA analysis indicates a satisfactory level of model fit. However, an even greater number of sample size could have added further evidence. Furthermore, the data was collected from only one of the maritime human resource supplier nations. Therefore, the results should be interpreted only in this narrow context. The data collection and comparison from geographical regions, other than the Philippines can shed further light on the level of digital proficiency of MET domain as a whole. It is also to be noted that the study was quantitative in nature. The collection of additional qualitative data through interviews or focused group discussions can add further perspective to the findings. Further studies are required to anticipate the skills requirement of the seafarers which could lead to more perspectives regarding the future education and training efforts needed to prepare the maritime workforce.

With increasing instances of technology being integrated in regular classrooms and on-the-job training, the maritime trainees would be expected to acquire, critique and construct knowledge along with their peers and therefore them having consideration of digital skills proficiency can facilitate the learning experiences. An understanding of digitalization and its impact is also necessary for the instructors who are facilitating learning and education in maritime classrooms, as well as the MET stakeholders at large, to ensure that the learning objectives can be met. The e-learning and distance learning solutions will enable the content to be produced or shared irrespective of the geographical barriers and therefore an effort towards assessing digital skills is also necessary. Future research could be directed to measuring and comparing the digital skills in other geographical regions that are also playing key role in human resource development for the maritime community.

6 Conclusion

In the present study, a standardized and validated scale – Youth Digital Skills Indicator (yDSI) was used to measure digital skills of the maritime trainees from the Philippines. The result indicate that the students rate their information navigation and processing skills along with the content creation and production skills lower than their technical and operation skills and the communication and interaction skills in the overall framework of digital skills. The reliability and validity of the yDSI questionnaire was found to be reasonable in the present context. Future research should be directed to comparison of similar data from other geographical regions as well as in-depth interviews and other qualitative studies that could further contribute in the ongoing efforts to address the digitalization related challenges and opportunities for the Maritime Education and Training sector.

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